Space Shuttle
Solid Rocket Motors
Thiokol Corporation

TWR-19984
ECS #: SS3415

Final Report for Failure Analysis of 1U52295-03 RSRM Safety and Arming Device S/N 0000016

13 November 1989

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

Contract No. NAS8-30490

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WBS.No. HQ-301

Thiokol CORPORATION
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TWR-19984

Final Report for Failure Analysis of 1U52295-03 RSRM Safety and Arming S/N 0000016

13 November 1989

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1.0 Introduction

This report documents the events which occurred during the analysis and disassembly of 1U52295-03 RSRM Safety and Arming Device (S&A) S/N 0000016, which failed acceptance checkout at Kennedy Space Center (KSC).

1.1 History

The S&A device was assembled at Thiokol from components built at the vendor, Eaton Corporation, Valve and Actuator Division (EVAD). All components had passed acceptance checkout tests at the vendor before shipment to Thiokol. When assembled into the loaded S&A configuration, the device passed the normal acceptance electrical checkout test specified in STW9-3269. When the device was shipped to KSC and acceptance tested, the unit failed to actuate and move to the arm position when voltage was applied to the motor circuits. No audible sound could be heard when power was applied to the device. Arming was attempted at 24 and 32 VDC with no results.

It was decided that the device should be shipped directly to EVAD from KSC for prompt disassembly and evaluation.

2.0 Applicable Documents

2.1 Thiokol Documents

1U50266	Arming-Monitor Assembly, S/A Device
1U50664	Bearing, ball
1U52293	Barrier-Booster Assembly
1U52294	Barrier-Booster Assembly, Loaded
1U52295	Safety and Arming Device, Rocket Motor
8U50364	Test Console Assembly
STW7-2767	Procedure, Individual Acceptance Test, Arming-Monitor Assembly (8U50364 Console)
STW7-2844	Procedure, Individual Electrical Checkout, S&A Device (8U50364 Console)
STW3-2654	Space Shuttle SRM Safety and Arming Device

2.2 Government Documents

EH14 (89-61)	Failure Analysis of SRM Safe and Arm Device (MSFC)
MAB-164-89	Failure Analysis of a GSE Cable used on the Ignition Safe and Arm (S&A) Test Device in the Ordnance Storage Facility (KSC)

2.3 Other Documents

FAR 2125	Failure Report (EVAD)

3.0 As Built Configuration

S&A Device	1U52295-03	S/N	0000016
Arming-Monitor	1U50266-02	S/N	0000042R2
Barrier-Booster	1U52293-02	S/N	0000098R1
Barrier-Booster	1U52294-02	S/N	0000020

4.0 Objective

The objective of this report is to present the findings of the failure analysis investigation. This report will cover the description of the failure, the procedure followed for disassembly, and the conclusions based on the findings of the failure analysis.

5.0 Summary

The primary contributing cause of the S&A failure at KSC was found to be the 1U50664-03 bearing located in the top of the Arming-Monitor assembly. The bearing, which was made of non-corrosion resistant steel, had evidence of corrosion which was later determined to be oxidation of the steel (reference Appendix A) to the extent that it caused the bearing to exhibit a high friction rate.

6.0 Conclusions and Recommendations

6.1 Conclusions

The 1U50664-03 bearing at the top of the Arming-Monitor motor housing had corroded to an extent which caused the motor operation to become intermittent.

6.2 Recommendations

6.2.1 The non-stainless steel ball bearings (1U50664-03, 1U50664-04) in the Arming-Monitor assembly should be replaced with appropriate bearings made of a suitable stainless steel (440C is the industry standard).

6.2.2 Shielded bearings should be pre-lubricated at the factory with the appropriate petroleum based lubricant, and should not be lubricated at EVAD. The MSFC report states that there was no detectible trace of lubricating oil on one of the bearings that they received, and the shields on the bearings prevented the lubricant applied at EVAD from penetrating into the bearing. Lack of proper lubrication can cause premature bearing wear and/or failure.

6.2.3 Bearings which are received at EVAD should be inspected to insure that they turn freely before they are installed into a unit.

6.2.4 The minimum cycle voltage and cycle times at 24.0 VDC should be re-evaluated for the Arming-Monitor assembly and the subassemblies. The current cycle time limit at 24 VDC for an Arming-Monitor is 1.0 second or less, and the minimum cycle voltage limit is 22 VDC or less. The average cycle time for an A-M is .689 seconds at 24 VDC, and the minimum cycle voltage average is 10.80 VDC. From these figures and the data obtained in this failure investigation, an Arming-Monitor which cycles above 0.8 seconds should be considered suspect. Large jumps in minimum cycle voltage after refurbishment should also flag a unit as suspect. S/N 42 Arming-Monitor experienced a 10 VDC increase in minimum cycle voltage when the bad bearing was inserted during refurbishment, and experienced a corresponding decrease when a good bearing was substituted during the failure investigation.

6.2.5 Data from electrical checkouts of other flight Arming-Monitors have been examined for evidence of similar problems. Units which have experienced large jumps in minimum cycle voltages (10 VDC or more) or increases in cycle times above .800 seconds after refurbishment should be considered suspect and immediately undergo bearing replacements.

6.2.6 Replacement of bearings on non-suspect units should occur as part of the normal refurbishment procedure.

7.0 <u>Discussion</u>

7.1 Problem Description

The main problem which was discovered with the unit was the intermittent operation of the S&A due to a corroded bearing.

7.2 Failure Analysis

7.2.1 Analysis Team

The S&A was packaged and delivered to the vendor's El Segundo, California facility in July 1989. Testing and disassembly was performed with the following team members present:

Tom Gregory	Thiokol Project Engineer
Lynn Hankins	Thiokol Program Manager
Dean Larson	Thiokol Quality Engineer
Steve Soffe	Thiokol Systems Safety
Tom Day	Thiokol Quality Source Representative
Joe B. Davis	NASA MSFC Engineering
Steve Reed	NASA MSFC Quality Engineer
Ed Worchester	EVAD Plant Manager
Bernie Marvin	EVAD Engineering Consultant
Herman Federman	EVAD Production Control
Judy Wideman	EVAD Contracts
Dan Cossette	EVAD Manufacturing Engineer

7.2.2 Testing

The failure analysis was performed in accordance with ETP-0518, with appropriate modifications. The S&A connector pins were examined for proper length and straightness, and no anomalies were found. Pin-to-pin resistances were checked with a multimeter, and all values were within design limits. The arm actuator resistance was 18.7Ω, which is within the 15-25Ω range allowed by design and is well within the normal value of 16-19Ω on most A-Ms

The 8U50364 S&A electrical checkout console was then used to determine the same resistance values, and the results were the same. The arm actuator resistance was measured at 18.6Ω. The S&A was then cycled at 24 VDC, and the cycle times to arm and safe were .905 and 1.014 seconds respectively (the allowable cycle time is 2.0 seconds maximum, and the average is .704 second).

At this point the loaded B-B assembly was removed from the S&A assembly. The B-B torque was measured with a torque watch gage and the torque in the arm and safe directions was 52 and 48 in-oz, respectively. There is no current limit on the amount of torque required to turn a 1U52293-02 Barrier-Booster lubricated with HD-2 grease and greater than 10% o-ring squeeze, that requirement was deleted as part of the HD-2 torque problem (it has been reinstated on the Krytox lubricated configuration).

The Arming-Monitor was then subjected to a complete electrical checkout per the normal acceptance test procedure (ATP) STW7-

2767. All cycle times were within specification limits, although higher than average, and all resistance checks were normal.

The Arming-Monitor was subjected to the vibration test specified in the ATP. The vibration simulates transportation vibration levels at 4.3 G_{rms} for 4 minutes per axis, 2 minutes in each position. The test was performed as follows:

1. Electrically arm at 28 VDC
2. Vibrate in the X-axis
3. Electrically safe at 28 VDC
4. Vibrate in the X-axis
5. Vibrate in the Y-axis
6. Electrically arm at 28 VDC
7. Vibrate in the Y-axis
8. Vibrate in the Z-axis
9. Attempt to electrically safe the unit at 28 VDC (test was stopped at this point when the unit did not move to the safe position.

Some of the vibration times were longer than planned, because the electrical connectors used to monitor position had fallen off the unit and had to be re-connected. When the attempt to electrically safe the Arming-Monitor failed, the test was stopped. The arm actuator resistance was measured with a multimeter and found to be 19.0Ω, and the other resistances were nominal. Cycle times were not obtained during the vibration test series, as the unit was cycled with a laboratory power supply instead of the test console. When the unit was energized, the circuit pulled 1.2 amps, which was within the normal range of .96 - 1.6 amps. The requirement for current draw is 3.0 amps or less.

The unit was manually safed with the safing pin insertion tool, and required 32 pounds of force to safe, which was well within the engineering requirement of 20-40 pounds force. When the unit was in the safe position, resistance readings were taken again. Arm motor resistance was 19.7Ω, and all other readings were normal.

At this point it was decided that the Arming-Monitor should be disassembled and examined for evidence of mechanical failure. It was theorized that a mechanical problem in the motor area was the most probable cause of the symptoms displayed by the unit. There was no apparent electrical problem, as the resistances and motor current were well within engineering limits. If a gear had failed in the gear train, some noise or vibration should have been evident in the unit when it was energized. A mechanical problem at the motor or the support bearings or electrical brushes would lock up the motor without causing noise or vibration, and would give normal electrical readings as well.

7.2.3 Arming-Monitor Teardown and Analysis

The Arming-Monitor assembly was disassembled with the team members present and looking for any signs of anomalies or malfunctions. As the unit was disassembled, each component was inspected for signs of damage. The only part which showed any discrepancies was the 1U50664-03 upper motor armature bearing (which is located at the very top of the Arming-Monitor, see Figure 1). The bearing could be turned, but felt very rough. Because this is a shielded bearing, a visual inspection of the balls and races could not be performed. After observing the suspect bearing, the actuator assembly was reassembled without the assembly screws torqued to final torque, and the motor ran freely. When the assembly screws were torqued to seating torque, the motor would not function. A replacement bearing was installed in the unit, and the motor performed well when the assembly screws were tightened. The cycle times also improved with the new bearing, and the minimum cycle voltage dropped almost 10 VDC.

7.2.4 Bearing Teardown and Analysis

The suspect bearing was sent to the Marshall Space Flight Center (MSFC) Lubrication and Surface Physics Branch for disassembly and analysis at the request of the NASA team members. The MSFC lab reported that the bearing was heavily rusted and had large flakes of rust in the ball races which could have caused the bearing to seize. The lab also reported that the bearing had probably not been lubricated with oil at the manufacturer, and that any additional lubrication at EVAD would not have been effective, due to the fact that this is a shielded bearing. A copy of the MSFC bearing analysis report is included in Appendix A.

7.2.5 KSC Cable Analysis

As part of the investigation, the electrical checkout console at KSC was examined for evidence of malfunction. During resistance checks of the test cable, it was observed that the resistance of the actuator cable conductor could be varied by squeezing the cable. A visual examination of the cable revealed nothing, however, by flexing the cable it showed that if the cable was held a certain way the actuator conductor was fully open, and would not have been able to actuate the S&A under test. The cable was X-rayed, and a break in the conductor was discovered.

It was determined by analysis of the Arming-Monitor that the cable was not a major contributing factor in the failure,

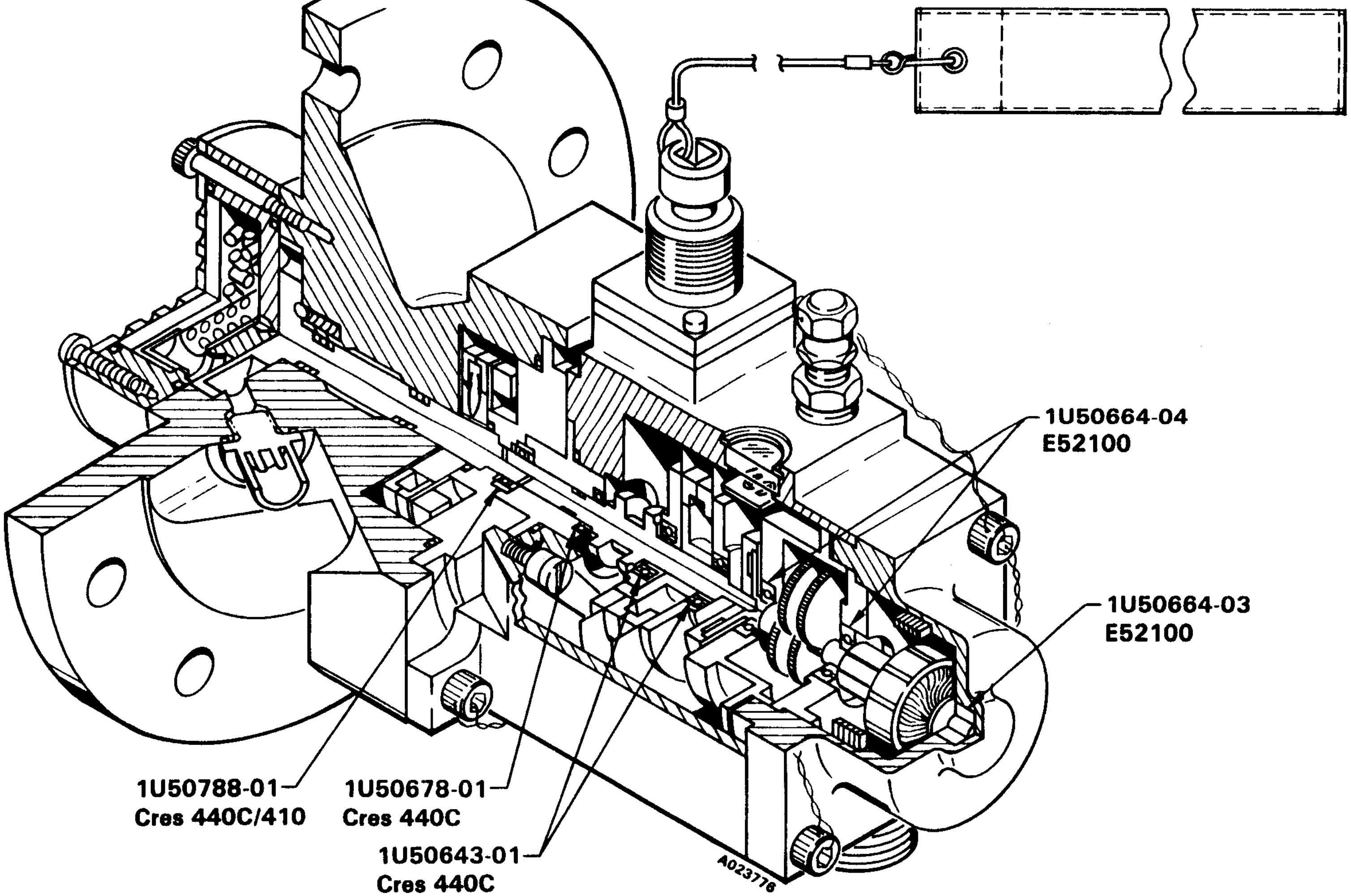


Figure 1

A-M and B-B Bearings

however, the cable has been taken out of service. The cable was not made by Thiokol for KSC, instead, KSC obtained the cable from an outside source. The cable was not properly marked with either part number or serial number. Discussions with NASA and Thiokol have determined that the cables will be marked with a proper part and serial number to prevent future confusion. A copy of the KSC cable analysis report is included in Appendix B.

7.3 Findings

The cause of the failure of the S&A to operate was the corroded 1U50664-03 bearing found in the Arming-Monitor assembly. During refurbishment, the bearing had been replaced, and the minimum cycle voltage increased nearly 10 VDC, and the cycle times also increased from 760 milliseconds to almost 900 milliseconds. The unit went through one use and then another refurbishment before the problem was noticed. The history of other Arming-Monitors has been examined for similar increases in cycle times and minimum cycle voltages to detect other bad Arming-Monitors before the problem is duplicated. Figures 2 and 3 show the cycle times and minimum cycle voltages for each serial number at each refurbishment. Several A-Ms, S/N 15, 19, 22, 28, 29, and 41, exhibit characteristics similar to the unit which failed. These A-Ms should be immediately refurbished and have the bearings replaced with new stainless steel bearings.

The existing bearings in the other Arming-Monitors will be replaced with stainless steel bearings during standard refurbishment. The stainless bearings are highly resistant to corrosion and will not cause a similar problem. EVAD uses stainless steel bearings of their other programs. The failure report from EVAD is included as appendix C.

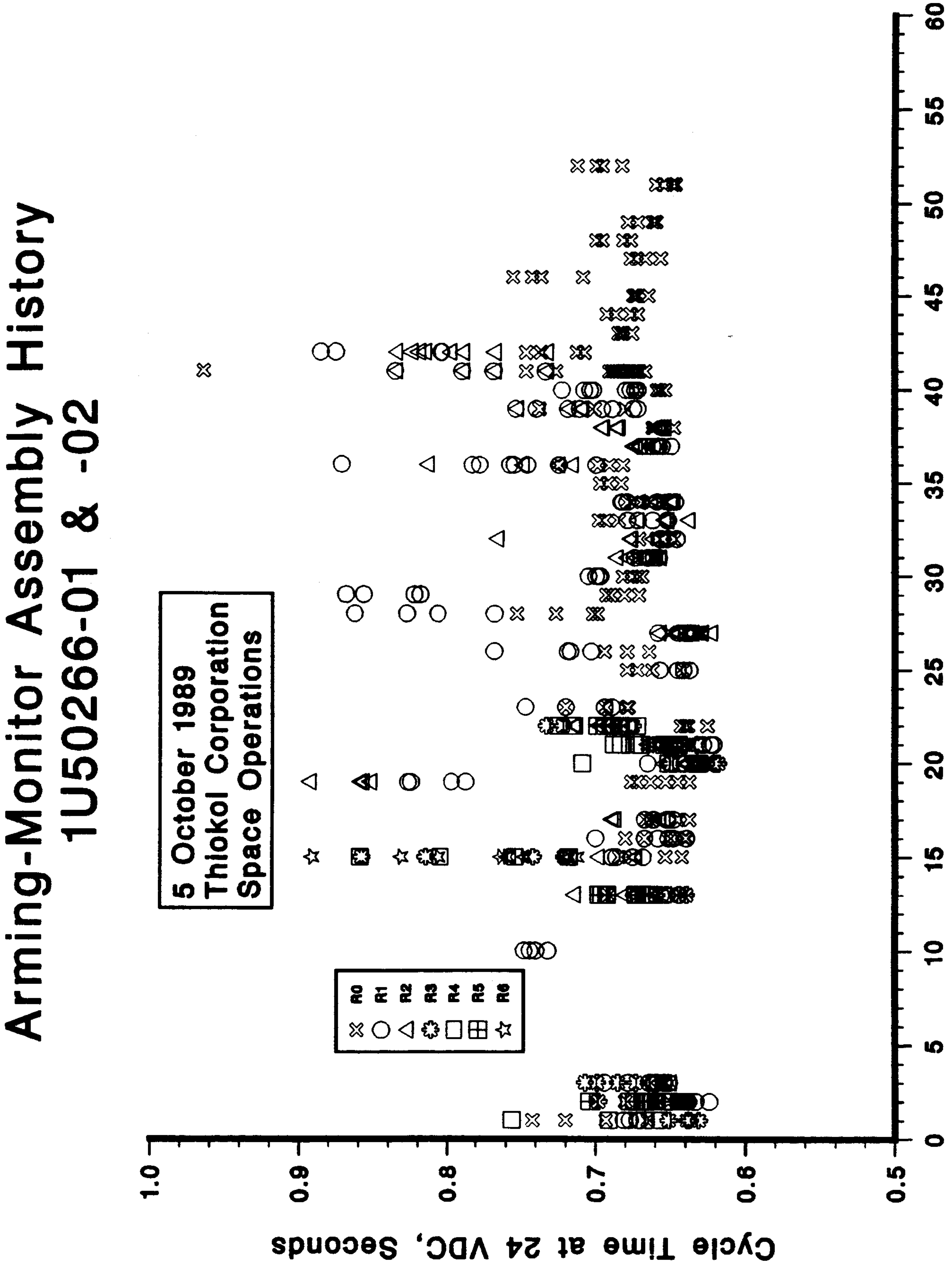


Figure 2 Cycle Times of New and Refurbished A-Ms

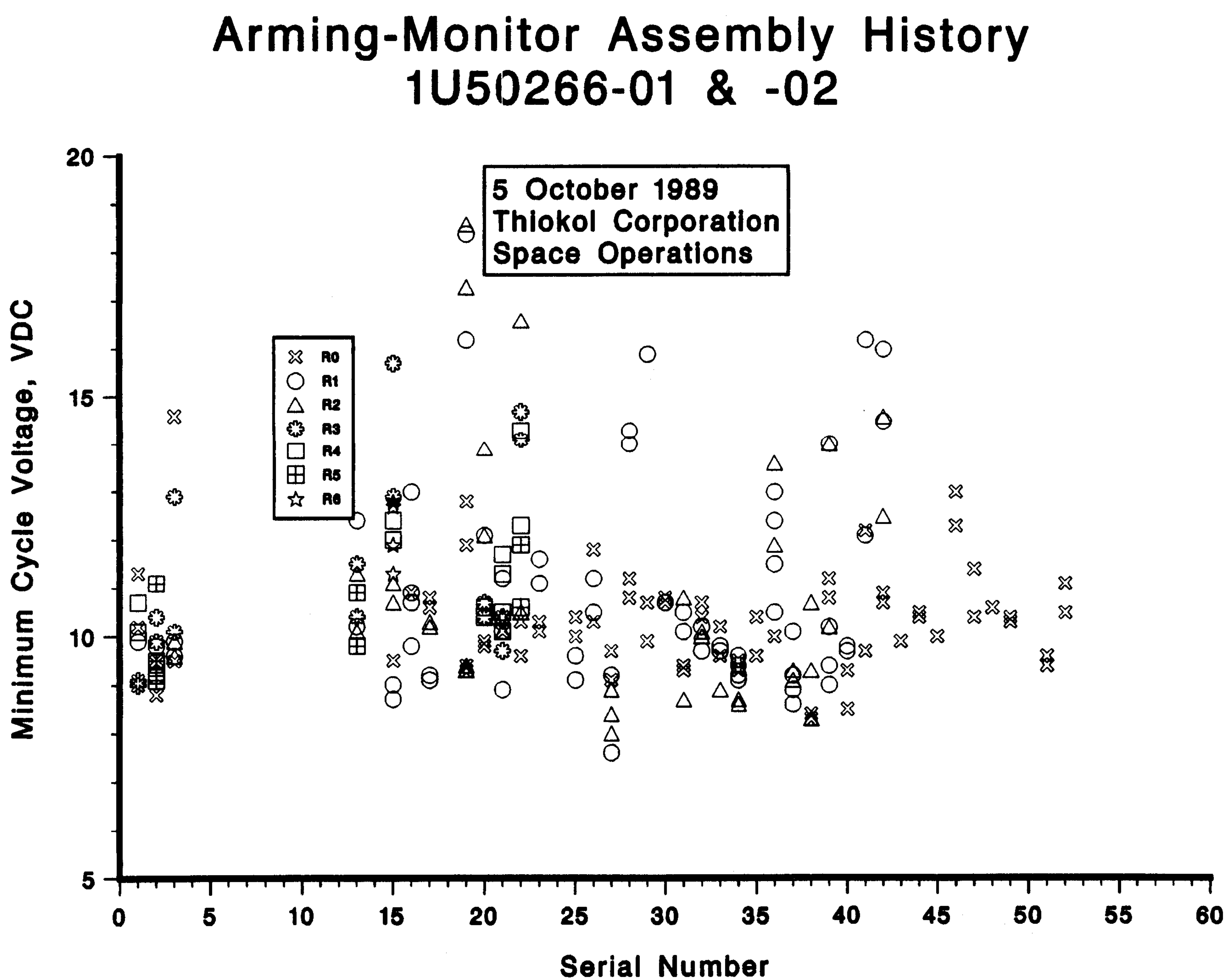


Figure 3 Minimum Cycle Voltage of New and Refurbished A-Ms

Appendix A

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

ly to Attn of: EH14(89-70) October 03, 1989

TO: For the Record

FROM: Paul H. Schuerer

SUBJECT: Failure Analysis of SRM Safe and Arm Device

On July 24, the Lubrication and Surface Physics Branch (EH14) received a suspect failed bearing and new replacement bearing from a Safe and Arm Device which had experienced a failure at KSC. The bearings were inspected visually using a microscope and analytically by using Electron Spectroscopy and Fourier Transform Infarared Spectroscopy. The following report, including pictures and enclosures, is the findings and recommendations for the SRM Safe and Arm Device. Further information can be obtained from Fred Dolan, 4-2512 or Howard Gibson, 4-2513.

Paul H. Schuerer
Director
Materials & Processes Laboratory

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

Reply to Attn of:

EH14 (89-61) September 12, 1989

TO: Distribution

FROM: EH11/Fred Dolan

SUBJECT: Failure Analysis of SRM Safe and Arm Device

On July 24th, the Lubrication and Surface Physics Branch (EH14) received two bearings from Messrs. Gordon Ross/EE51 and Joe Davis/ED53. One was a suspect bearing from a failed Safe and Arm Device, P/N 1U52295-03, SN 16, and the other was reported to be a new replacement bearing for that same Safe and Arm Device assembly. This Safe and Arm assembly had operated properly at Thiokol, would not operate at KSC, and was returned to Eaton Corporation, where it also operated correctly. Disassembly of the arming device at Eaton revealed a suspect motor shaft bearing (see Figure 1). The bearings were Thiokol P/N 1U50664, which are 0.375" O.D., 0.125" bore bearings, made of AISI 52100 high carbon steel. These bearings had been brought from Morton Thiokol, Utah. Both bearings were examined as assemblies and in step by step fashion during disassembly using a microscope at 10-32X. Photographs were taken as disassembly and inspection progressed. The following is a summary of the findings.

<u>Failed Bearing</u>

1. Iron oxide was noted on the inner race bore. (Figure 2)

2. The inner race ball track had a uniform rust color. (Figure 3)

3. Iron oxide was observed on the inside of both shields.

4. Large areas of iron oxide were in evidence on and inside the crown type ball cage. (Figure 4)

5. Iron oxide was prevalent in the outer race with many loose flakes of the same. (Figure 5)

6. All the balls had a uniform bronze/orange coating of iron oxide. The ball surfaces were slightly pitted. (Figure 6)

7. A small amount of white nonmetallic residue was noted on the inner race and outer race away from the ball tracks. (Figure 7)

Replacement Bearing

1. Three small surface spots that appeared to be rust were noted on the outside of one shield. (Figure 8)

2. Very small dabs of white lubricant inside the crown ball cage were observed. (Figure 9)

3. A very small amount of whitish, nonmetallic residue was found on the outside edge of the outer race. (Figure 10)

4. All other surfaces were free from oxidation or debris. (Figure 11)

It was further noted that the bearing drawing references a MIL-L-6085 oil as the lubricant to be used. This is a low viscosity, corrosion resistant, synthetic instrument oil. There was no visible evidence that this oil was present.

In order to have more in-depth analyses performed on the two bearings, they were taken to other Branches within the Laboratory. The new one was delivered to the Analytical and Physical Chemistry Branch, EH32, for an analysis of the residual nonmetallic material suspected of being a lubricant. The failed one was taken to the Metallurgical and Failure Analysis Branch, EH22, for surface analyses of selected balls and races to verify or refute the presence of corrosion on internal parts of the bearing.

Chemical analysis of the residue in the new bearing by EH32 using FTIR (Fourier Transform Infrared Spectroscopy) indicated that it was a type of organic salt with either a long chain or ring hydrocarbon at the end. (For additional information, see Enclosure 1.) The analysis indicates a small amount of residual grease; the organic salt was the thickener and the hydrocarbon was the oil which when mixed form a grease. Again, the FTIR analysis indicated that the small dabs of white nonmetallic residue were residual lubricant. These are believed to have been a residue left when the manufacturer or a distributor attempted to clean grease lubricated bearings which had non-removable shields already installed. This was undoubtedly, attempted in order to supply clean, dry bearings from those already in stack as ordered by Eaton, manufacturer of the Arming and Monitor Assembly P/N 1U50266-02, portion of the S&A Device. The above has been confirmed by Mr. Joe Davis, ED53, on a recent fact finding visit to the Eaton plant. This fact finding visit also revealed that 8 of 13 of these bearings which Eaton had in stock also contained corrosion which was evident upon close visual inspection. These facts certainly confirm a bearing vendor's concern years ago when his technical representative related a personal experience with shipping clean, dry bearings made of AISI 52100 steel. He stated that even though properly packaged they will often be corroded by the time they reach their destination. As a result of a similar problem that company adopted a new rule: Never ship or store clean dry 52100 bearings as it would almost assuredly result in corrosion problems. In this situation, another lesson learned, again.

ESCA (Electron Spectroscopy for Chemical Analysis) analysis of the failed bearing by EH22 resulted in the identification of iron oxides, some iron, and two types of hydrocarbons. (For additional details see Enclosure 2.)

The ESCA (XPS) analyses confirmed that corrosion was present in the form of Fe_2O_3 and Fe_3O_4 along with two types of hydrocarbons. It was also found that some of the oxygen in the oxide contained a hydroxide (OH) indicating that moisture had contributed to the corrosion. It is unknown whether all the corrosion formed while the bearing was clean and dry, or whether some formed after the attempt to add the required one drop of MIL-L-6085 synthetic diester oil. As was previously noted the bearing already had unremovable shields installed making cleaning and relubrication very difficult. Also previously mentioned was the fact that there was no visual evidence that this oil had been added; however, ESCA results revealed some evidence of two types of hydrocarbons were present, indicating some of the synthetic oil may have made its way inside the bearing.

The point of all this is as follows:

1. A synthetic oil was specified for use.

2. Usage requirements did not necessarily require a synthetic, i.e.,

a. A very wide temperature range was not necessary, approximately $20^{\circ}F$ to $135^{\circ}F$,

b. Oxygen compatibility was not required. The bearing is sealed in a GN_2 environment.

c. Low outgassing was not necessary. See item b immediately above.

3. Synthetics tend to have some disadvantages as well as advantages. These are:

a. They tend to be hygroscopic; they can tend to promote corrosion.

b. Most, better anti-corrosion additives are immiscible in synthetic oils. Often less effective additives are used.

c. EH14 has noted that 440C (CRES) steel bearings operating in a humid environments, approximately 95% relative humidity, with synthetic lubricants often have some evidence of corrosion internally after one year of operation. This, of course, indicates less effective corrosion resistance properties than typical mineral oil based greases typically have.

4. Consequently, if a synthetic oil is not required and if corrosion is a possibility, mineral oils or mineral oil based greases are recommended. A mineral oil based grease is recommended for this application even if a material change to 440C is made. A more specific recommendation will be made later in this letter.

The quantity, size, and location of rust particles found in the inner and outer races of the failed bearing were carefully observed visually. Several larger rust particles (flakes) were noted to be adhered to the active raceways as a result of having been run over by the balls. This situation existed on both the inner and outer raceways, see Figures 3 and 5. Since these flakes of rust on the raceways have a thickness they serve to reduce the internal clearance inside the bearings, which is typically 0.0003 to 0.0006 inch in a bearing of this type and size. With a reduction in clearance caused by these flakes an additional bit of loose rust or debris even of small size could very likely be a cause for the bearing to jam or require a higher than normal torque to turn it. These rust flakes noted inside the bearing are considered to be a highly likely cause for failure to operate at KSC, yet operate later after transportation shock and vibration had caused the loose particles to become repositioned.

The Safe and Arm Device application was reviewed with the SRM Tiger Team and recommendations were made to change the bearing drawing to require a better precision class, i.e., ABEC-5 or ABEC-7, made of 440C steel, and to use a MIL-G-81322D grease or Exxon Andok B, a Mil-G-18709 grease for lubrication. The former are less viscous, low temperature greases; the latter is a wide temperature, corrosion inhibiting, mineral oil base lube. The Safe and Arm Device contains five of these bearings, any of which could cause a similar failure. In addition, a minimum operating voltage check is being proposed by others to screen for defective Safe and Arm units until a solution is incorporated. We agree with this screening test method and endorse its use as well.

Fred J. Dolan

Fred J. Dolan
Deputy Chief
Engineering Physics Division

Enclosures

Distribution:
ED53/J. Davis
EE51/G. Ross
EH11/A. Whitaker
EH11/F. Dolan
EH14/H. Gibson
EH22/P. Munafo
EH22/I. Dalins
EH32/S. Caruso
MTI/J. Webb
MTI/I. Adams
MTI/T. Pinkerman
MTI/W. McCreary

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
AC(205)544-2121

NASA

Reply to Attn of: EH32 (89-341) August 30, 1989

TO: EH14/F. J. Dolan

FROM: EH32/S. V. Caruso

SUBJECT: SRB Safe and Arm Bearing Analysis by FTIR

As you requested, the subject sample has been analyzed (EH32-89-250). Fourier transform infrared (FTIR) spectroscopy analysis indicated that the sample was a type of organic salt with either a long chain hydrocarbon substituted at the end or a ring (cyclo) hydrocarbon. Since the sample quantity was very small, further methods could not be performed to completely determine the chemical structure of the sample.

If you have any questions, please call Ms. Diep Trinh at 544-6797.

S. V. Caruso

S. V. Caruso
Chief, Analytical and
Physical Chemistry Branch

cc:
EH31/Mr. McIntosh
EH32/Ms. Trinh

EH22 (89-96) August 9, 1989

MEMORANDUM FOR RECORD

FROM: EH22/I. Dalins

SUBJECT: ESCA(XPS) Analysis of Small Ball Bearing Parts For SRB (Thiokol)

Three small balls, the metal ring that is part of the bearing seal, the inner race and the outer race were analyzed using the recently installed SSI-100 ESCA Probe in survey, depth profile and detail spectral line analysis modes. The data show that the contaminated bearing surface contains several iron oxides (Fe_2O_3 and Fe_3O_4 and some iron metal) with a mixture of at least two types of hydrocarbons. The oxygen spectra show also that OH type of oxygen is present, which indicates that moisture has contributed to the corrosion of the bearing parts.

Data traces have been retained in EH22 files.

Imants Dalins
I. Dalins
Metallurgical & Failure
Analysis Branch

ORGANIZATION: ED53	MARSHALL SPACE FLIGHT CENTER	NAME: HANS J. NEIN
CHART NO.:	**SRM IGNITION SYSTEM S&A DEVICE**	DATE: JULY 1989

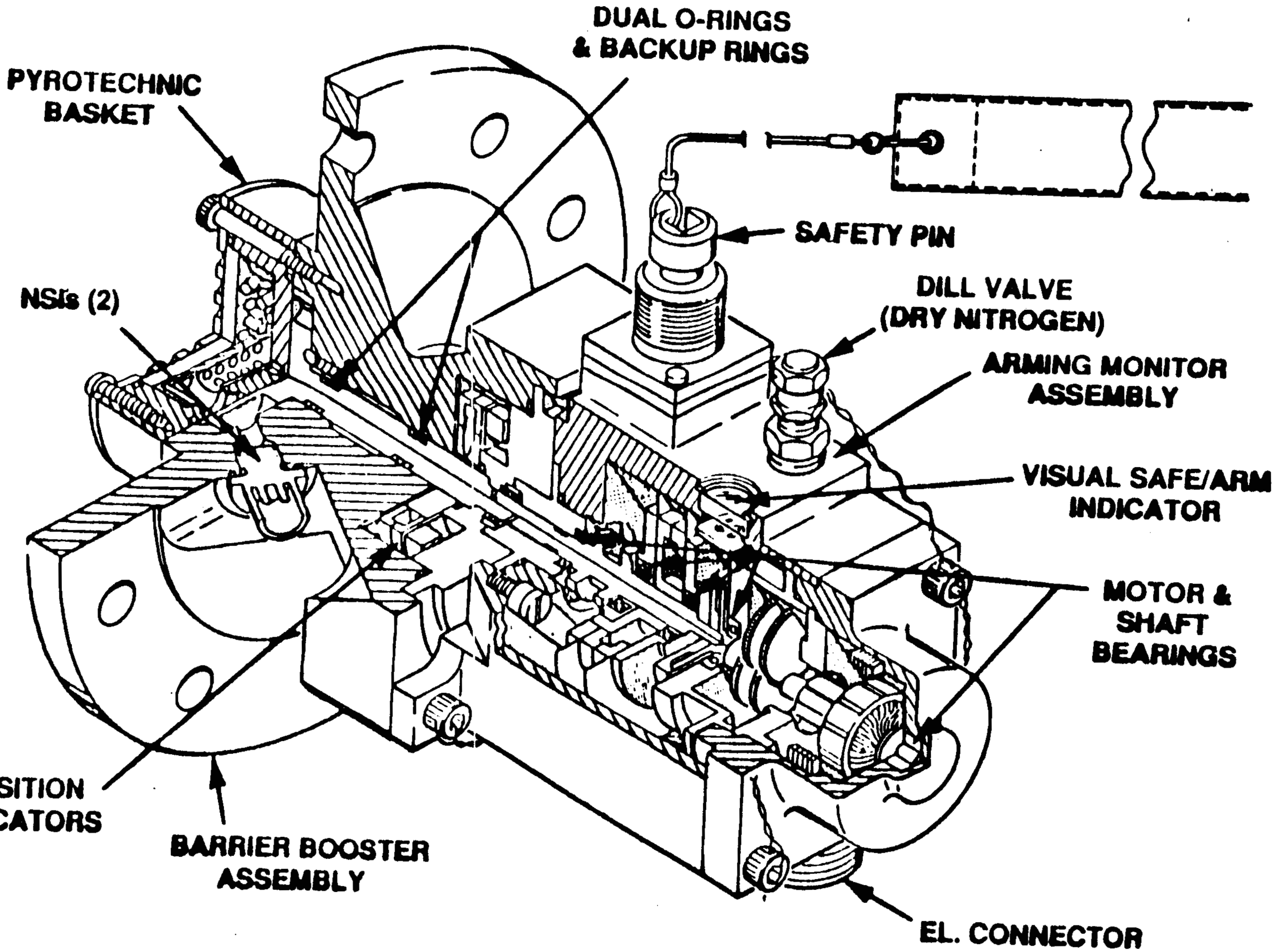


Figure 1

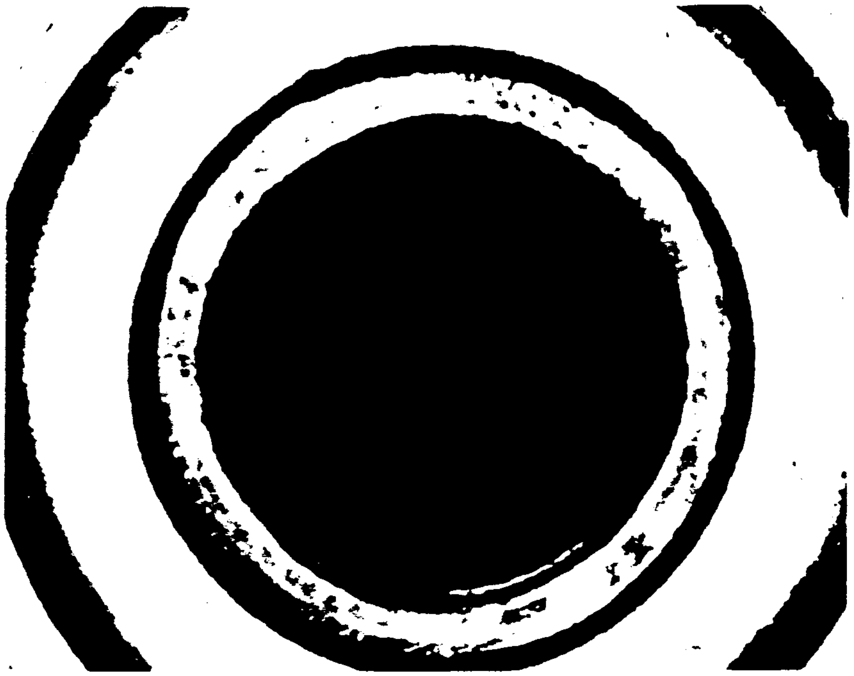


Figure 2. Iron Oxide on Bearing Inner Race Bore

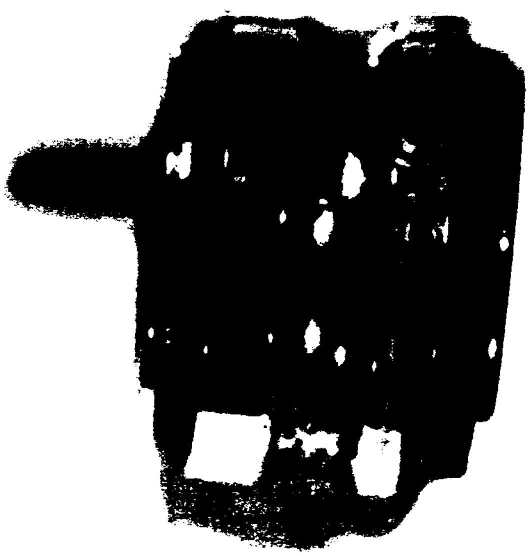


Figure 3. Inner Race. Note large flakes in ball track.

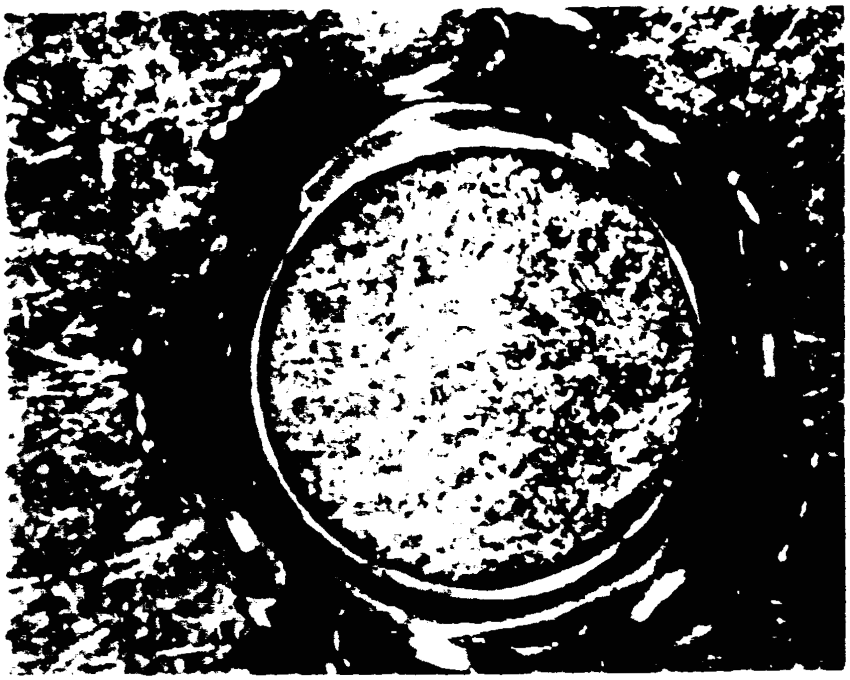


Figure 4. Ball Separator

Figure 5. Outer Race. Note loose flakes of material.

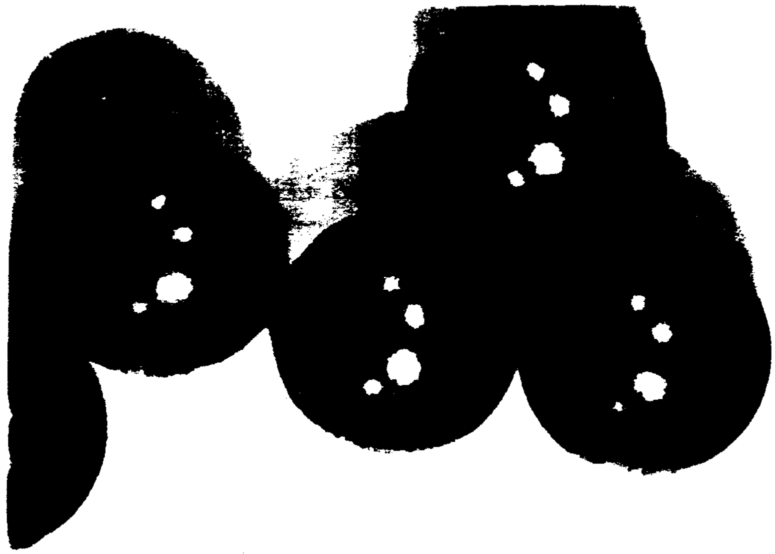


Figure 6. Balls. Note the adherence of material on the side of the balls.

Figure 7. Outer Race showing white nonmetallic residue

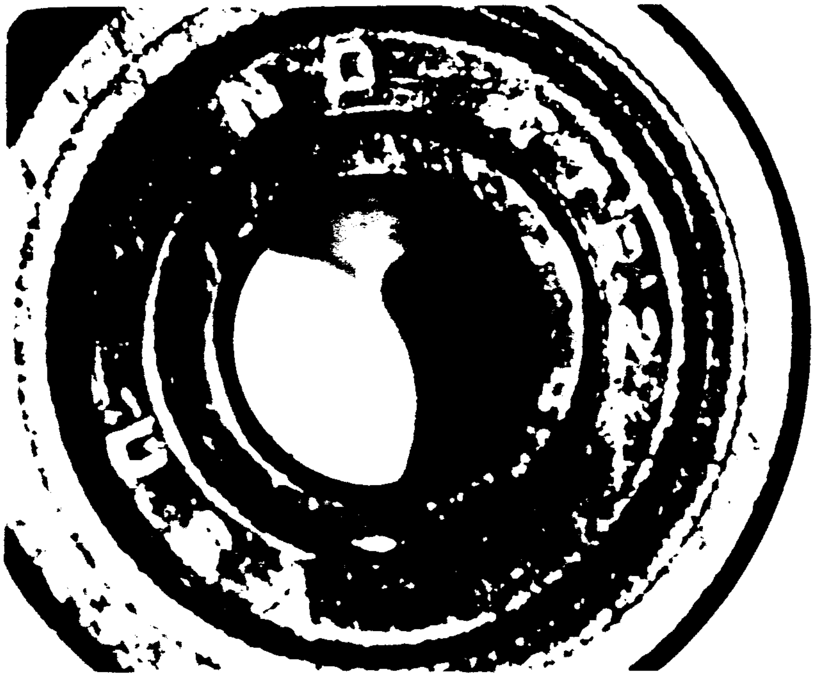


Figure 8. Replacement Bearing. Rust spots at 11, 1, and 7 o'clock

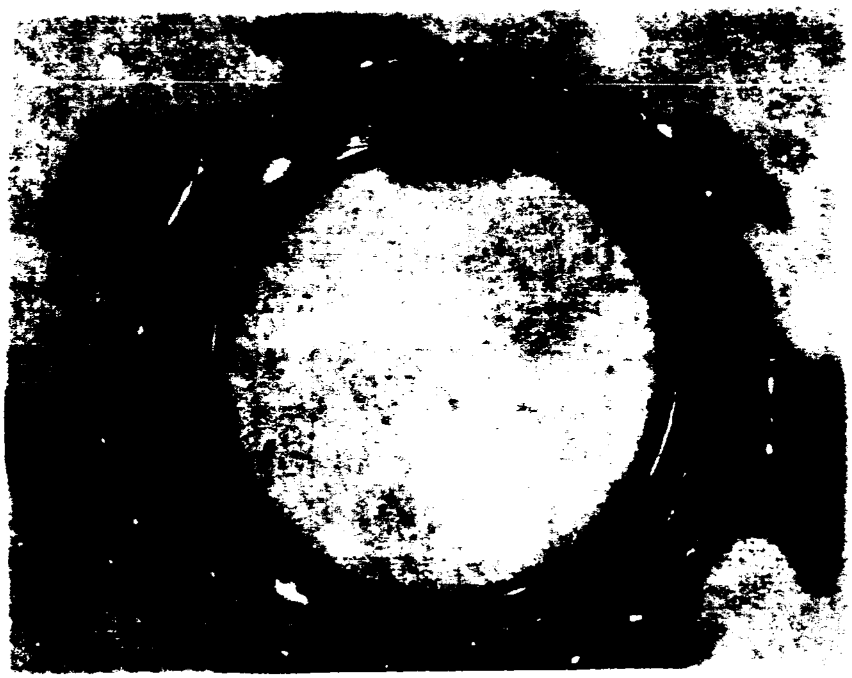


Figure 9. Ball Separator. White areas are lubricant.

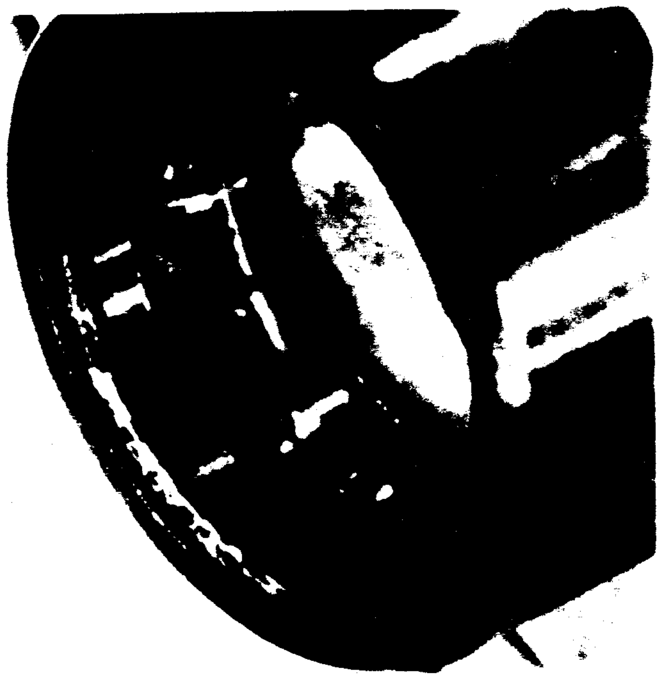


Figure 10. Outer Race with grease residue on outer edges

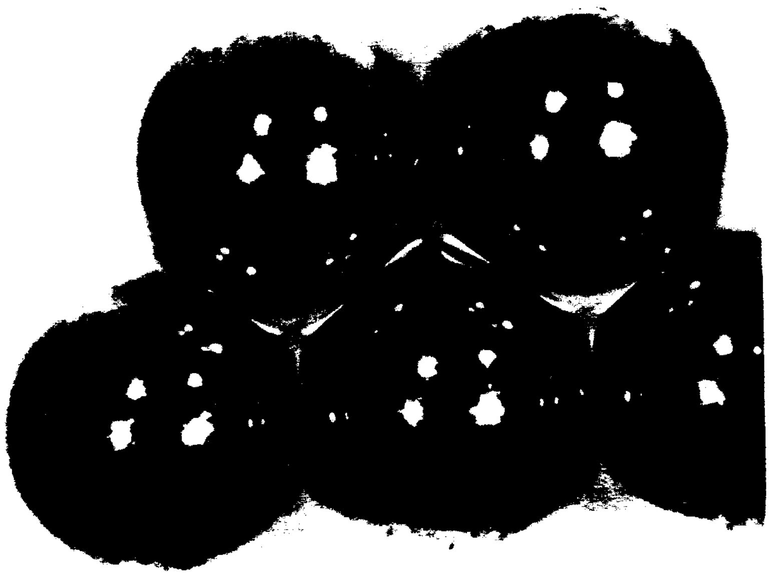


Figure 11. Balls from replacement bearing

Appendix B

NASA

DIRECTOR OF ENGINEERING DEVELOPMENT

DIRECTOR, MECHANICAL ENGINEERING

MATERIALS SCIENCE LABORATORY

MALFUNCTION ANALYSIS BRANCH

DM-MSL-3, ROOM 2217, O&C BUILDING

KENNEDY SPACE CENTER, FLORIDA 32899

SEPTEMBER 14, 1989

MAB-164-89

SUBJECT: Failure Analysis of a GSE Cable used on the Ignition Safe & Arm (S&A) Test Device in the Ordnance Storage Facility

RELATED DOCUMENTATION: Schematic 8U50539, OMI S-6005

1.0 FOREWORD

1.1 The subject cable, which was manufactured by the Launch Equipment Services Cable Shop, is used to connect the Ignition Safe and Arm to the portable Ignition S&A Test Device. Reportedly, the subject cable malfunctioned during use, and subsequent troubleshooting detected an intermittent electrical open between pin B of connector JT2 and pins H and J of connector JT1.

1.2 The subject cable was submitted by Lockheed Space Operations Company (LSOC) personnel to the Malfunction Analysis Branch (MAB) for failure analysis.

2.0 INVESTIGATIVE PROCEDURES

2.1 A photograph of the cable is shown in Figure 1. Using an ohm meter, the continuity of the cable was completely tested. The intermittent electrical open between pin B of connector JT2 and pins H and J of connector JT1 was confirmed. The electrical resistance of this conduction path was very sensitive to flexing of the cable near connector JT2. Flexing the cable in one direction caused the conductor to open. Flexing the cable in the opposite direction caused the conductor to close. Irregularities were felt along the wires inside the cable jacket at the point which was the most sensitive to the flexing.

2.2 Radiographs of the fault location are shown in Figure 2. These radiographs show that the irregularities inside the cable jacket were wire splicing devices. The radiographs also show a free wire end near the end of one of the wire splicing devices.

2.3 Figure 3 shows photographs of connector JT2 and the faulty portion of the cable. Figure 4 shows photographs of the faulty portion of the cable after the connector label was removed from the cable jacket.

2.4 The cable jacket was opened in the vicinity of the fault revealing a crimp connector covered with heat shrink tubing as shown in Figure 5. The free wire end was pulled out of the heat shrink tubing revealing the tangled wire strands at the end of the wire as shown in Figure 6.

2.5 The heat shrink tubing was removed from the crimp connector as shown in Figure 7. The end of the free wire shown in Figure 8 had scrape marks on the wire strands and necking of the ends of the strands. Figure 9 shows the end of the crimp connector. Some wire strands broke at the end of the crimp connector while others stretched and broke some distance from the end of the crimp connector.

3.0 DISCUSSION

3.1 The use of crimp connectors in the flexible portion of the cable made the cable very susceptible to continuity failure. Crimp connections are not very tolerant of the frequent flexing and tension to which such test equipment cables are exposed.

3.2 The susceptibility of the cable to continuity failure was aggravated by the placement of the crimp connectors near a cable connector. In the case of equipment cables which are frequently connected and disconnected, the portions of the cables nearest the cable connectors usually experience the greatest amounts of flexing stress and pulling.

3.3 The connections which were formed by the splices were essential for correct functioning of the cable. The subject failure was not a consequence of the existence of the connections. It was a consequence of the method used to form the connections, the location of the connections in the cable and the lack of use of strain relief devices at the connections.

4.0 CONCLUSIONS AND RECOMMENDATIONS

It is suggested that consideration be given to redesigning the cable in order to isolate all connections from flexing and tension and/or make connections less prone to failure due to flexing and tension.

INVESTIGATOR: Jeffrey Rauwerdink
JEFFREY RAUWERDINK

APPROVED: [illegible signature]
C. R. DENABURG, CHIEF, MAB, NASA

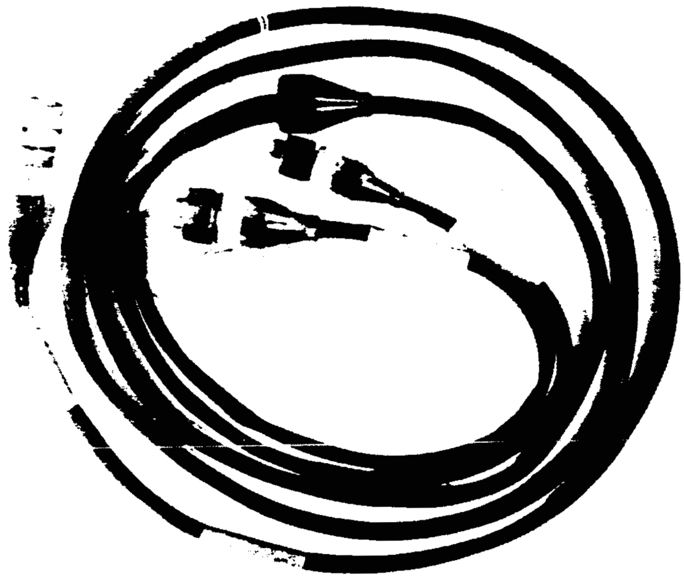


FIGURE 1

PHOTOGRAPH OF THE CABLE IN THE "AS RECEIVED" CONDITION.
MAGNIFICATION: 0.27X

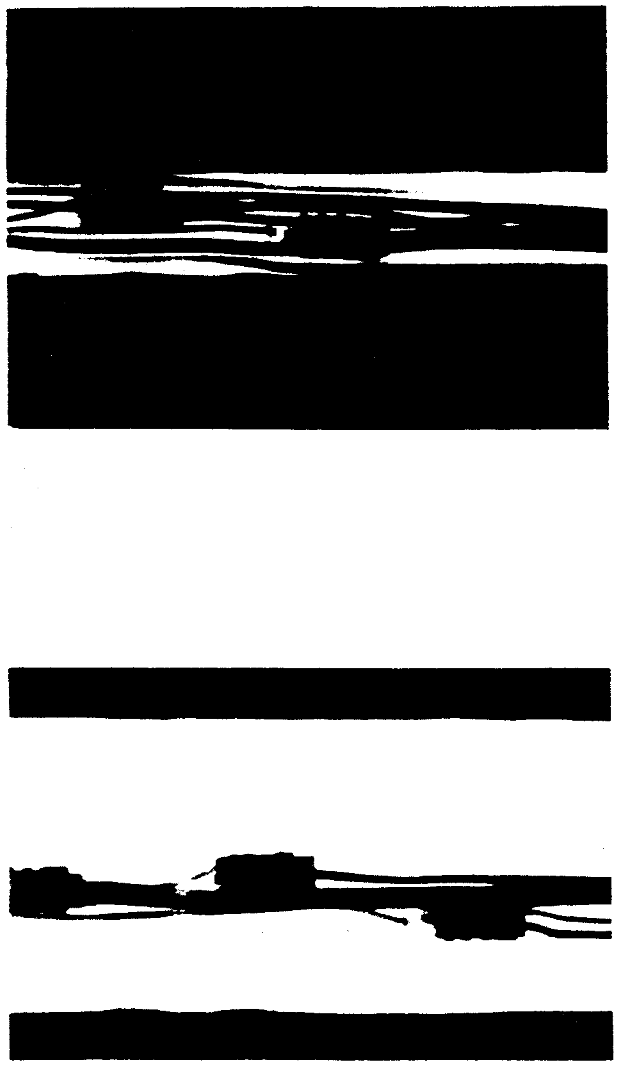


FIGURE 2

RADIOGRAPHS OF THE FAULT LOCATION.
MAGNIFICATION: BOTH 1.4X

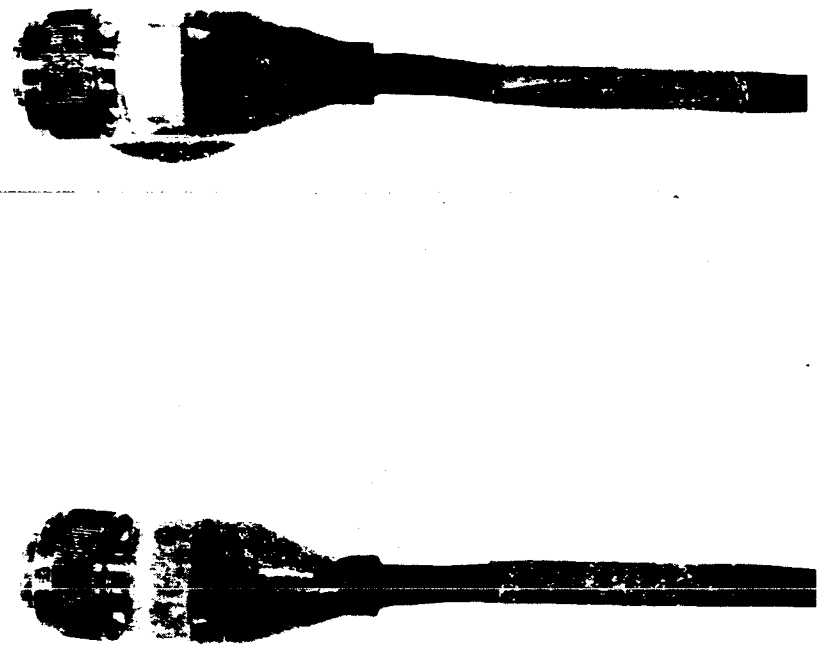


FIGURE 3

PHOTOGRAPHS OF CONNECTOR JT2 AND THE FAULTY PORTION OF THE CABLE.

MAGNIFICATION: BOTH 0.65X

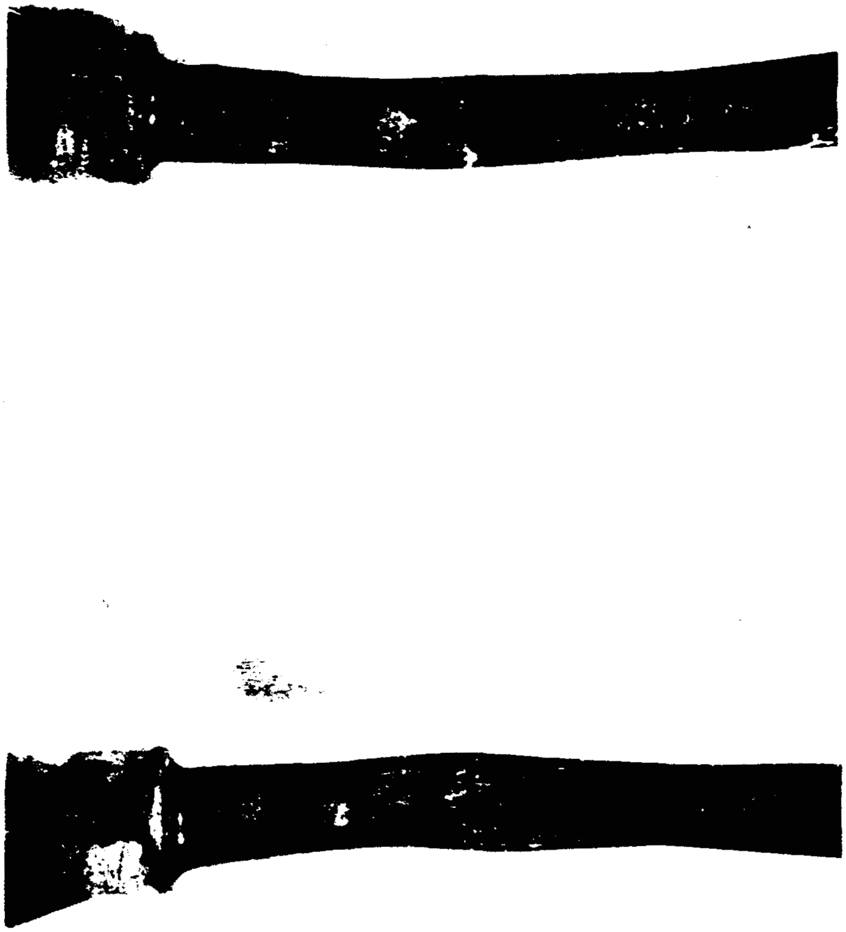


FIGURE 4

PHOTOGRAPHS OF THE FAULTY PORTION OF THE CABLE AFTER THE CONNECTOR LABEL WAS REMOVED.
MAGNIFICATION: BOTH 1.4X

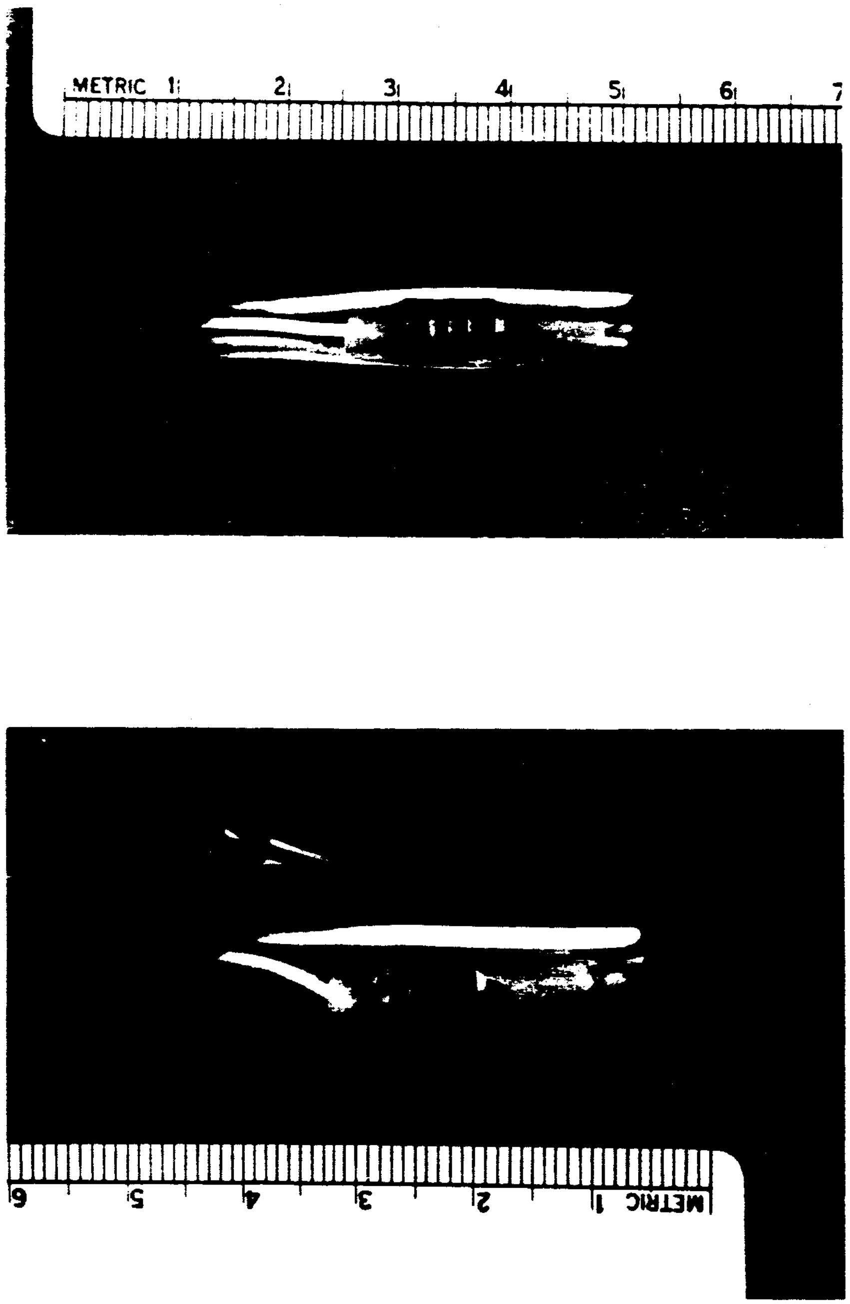


FIGURE 5

PHOTOGRAPHS OF THE FAULTY PORTION OF THE CABLE WITH THE CABLE JACKET OPENED.

MAGNIFICATION: BOTH 1.5X

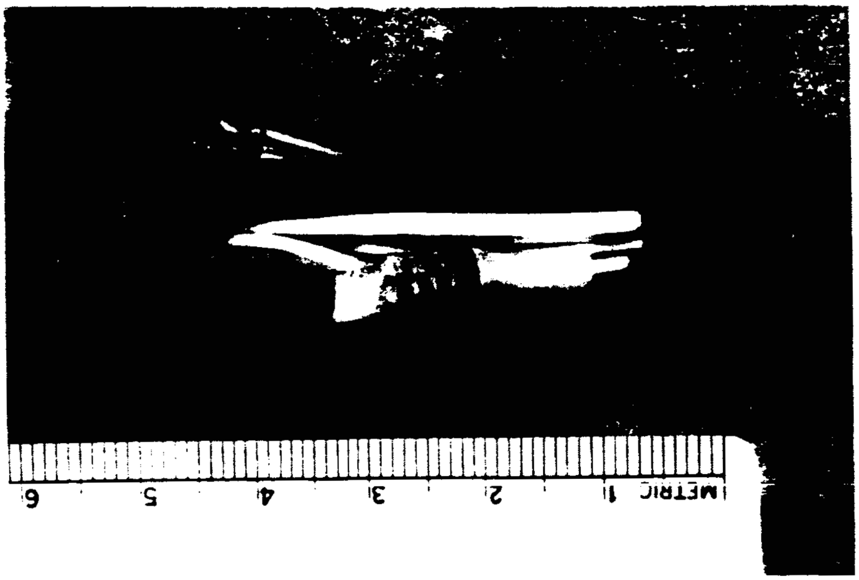
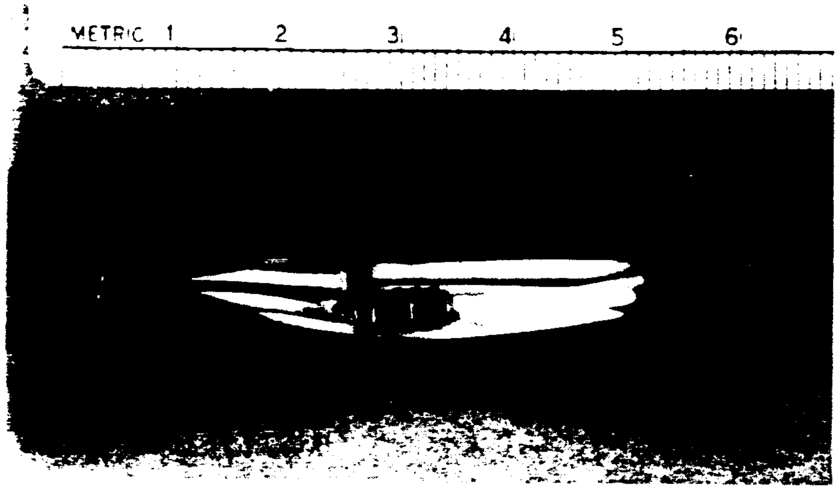


FIGURE 6

PHOTOGRAPH OF THE FAULTY PORTION OF THE CABLE WITH THE FREE WIRE END OUTSIDE OF THE HEAT SHRINK TUBING.
MAGNIFICATION: 1.5X



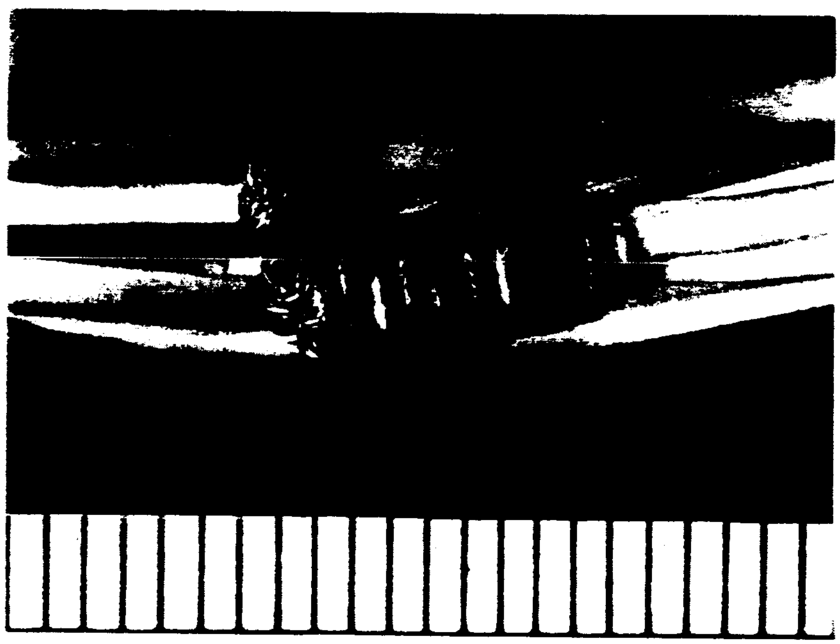


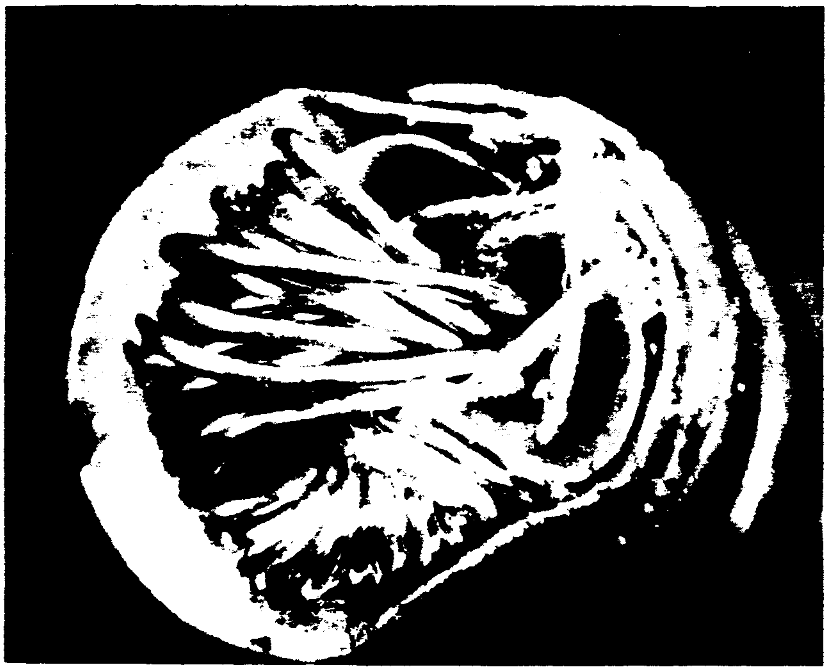
FIGURE 7

PHOTOGRAPHS OF THE CRIMP CONNECTOR WITH THE HEAT SHRINK TUBING REMOVED.

MAGNIFICATION: UPPER 1.5X
LOWER 4.9X

FIGURE 8

PHOTOGRAPH OF THE FREE WIRE END.
MAGNIFICATION: 30X



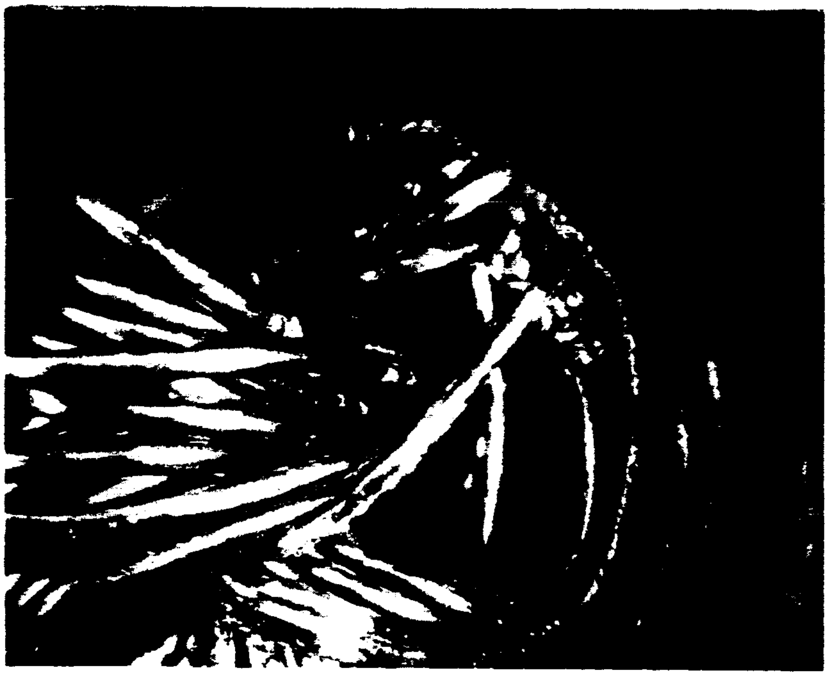


FIGURE 9

PHOTOGRAPH OF THE END OF THE CRIMP CONNECTOR.
MAGNIFICATION: UPPER 18X
LOWER 25X

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Appendix C

FAILURE REPORT

REPORT NO.: 2125 DATE: 7/18/89 CUSTOMER: THIOKOL

UNIT NAME: ARMING MONITOR SALES ORDER NO.: RX22

E.C.C. PART NO.: 1U50266-02 SERIAL NO.: 0000042R2

CUSTOMER P.O. NO.: DRR001 GOV'T CONTRACT NO.: NAS-8-30490

CUSTOMER PART NO.: 1U52295-03 FAILURE DATE: JULY 1989

DISCREPANT SUB-ASSEMBLY PART NAME: N/A

PART NO.: N/A REVISION N/A LOT NO. N/A

FAILURE LEVEL: FIELD TIME PRIOR TO FAILURE: UNKNOWN

A.T.P.: STW9-3269 PARA.: VARIOUS TITLE: ______

I. DISCREPANCY: UNIT FAILED TO ARM WHILE BEING TESTED AT KENNEDY SPA CENTER (KSC). (REF THIOKOL UPDATED ETP-0518 DATED JULY 89 - ATCH #1)

II. PROBABLE CAUSE OF FAILURE: VARIOUS PROBABLE CAUSES. (SEE FAILURE INVESTIGATION OF S & A DEVICE 016 DATED 20 JULY 1989, 12:30 P.M. MDT -ATCH #2)

III. DISPOSITION OF UNIT: UNIT SHALL BE RE-BUILT PER DIRECTION FROM THIOKOL.

IV. CONCLUSION: SEE ATCH #3 AND ADDENDUM 1 AND 2 TO ATCH #3

V. RECOMMENDATIONS: SEE ATCH #3 AND ADDENDUM 1 & 2 TO ATCH #3

8/23/89 8/25/89 8-25-89

DESIGN ENG./DATE RELIABILITY ENG./DATE QUALITY ENG.DATE

1.0 Introduction

This document outlines the procedure for disassembly and evaluation of 1U52295-03 RSRM Safety and Arming Device (S & A) S/N 0000016, which failed acceptance checkout at Kennedy Space Center (KSC).

1.1. History

The suspect S&A device was assembled at Thiokol from components built at the vendor, Eaton Consolidated Controls (ECC). All components had passed acceptance checkout tests at the vendor before shipment to Thiokol. When assembled into the loaded S & A configuration, the device passed the acceptance checkout test specified in STW9-3269. When the device was shipped to KSC, the unit failed to actuate and move to the arm position when voltage was applied to the motor circuits. No sound could be heard when power was applied to the Safe & Arm Device. Such a sound would be an indication that the motor was trying to operate. Arming was attempted at 24 and 32 VDC with no results.

It was decided that the device should be shipped directly to ECC form KSC for prompt disassembly and evaluation.

As Built Configuration

S&A Device	1U52295-03 S/N 0000016
Arming-Monitor	1U50266-02 S/N 0000042R2
Barrier-Booster	1U52293-02 S/N 0000098R1
Barrier-Booster	1U52294-02 S/N 0000020

2.0 Applicable Documents

1U52293	Barrier-Booster Assembly
1U52294	Barrier-Booster Assembly, Loaded
1U52295	Safety and Arming Device, Rocket Motor
2U66597	Torque Measurement Fixture
8U50364	Test Console Assembly
STW7-2767	Procedure, Individual Acceptance Test, Arming-Monitor Assembly (8U50364 Console)
STW7-2844	Procedure, Individual Electrical Checkout,

3.0 Instrumentation

The instrumentation needed for this failure analysis is listed below. Other instrumentation may be substituted provided that it is equivalent in function and increases the accuracy and repeatability of the tests.

Torque Watch Gage, 0-40 in-oz., +/-2%

Torque watch Gage, 0-200 in-oz, +/-2%

Ohmmeter/Multimeter, +/-2%

4.0 Procedure

Note: Q.C. (Q.C.R.), NASA, and government observation and verification is mandatory for the disassembly and electrical checkout portion of this procedure.

Note: This plan may be redlined by the investigation team as required. Such changes will be documented in the test report.

4.1 Pre-test

4.1.1 Review all data from previous checkouts.

4.1.2 All data and observations shall be recorded.

4.1.3 Visually inspect and record conditions of all components. Some of the conditions which should be looked for are:

Bent or broken connector pins

Proper pin length

Damage to Arming-Monitor case or connector

Damage to shipping container

Loose or unfastened parts

4.1.4 Pin-to-pin check on the A-M connector per attachment A with a standard ohmmeter/multimeter.

4.2 Pyrotechnic down loading (see para 4.3.7.1)

4.3 Test

Note: Paragraphs 4.3.1 thru 4.3.4 should be done regardless of the results of previous tests.

4.3.1 Using an 8U50364 S&A test console, perform a self test of the console per STW7-2844, paragraph 3.4.2.2. (ALL checkout specification documents shall be STW7-2844 unless otherwise specified.)

4.3.2 Perform an arm actuator resistance check per paragraph 4.3.3, steps 28 through 31. Allowable values are 15-25 Ohms.

4.3.3 Perform a safe position monitor resistance test of the Arming-Monitor switch deck per STW7-2767, paragraph 4.3.4, steps 32 through 35. Allowable values are 0-200 milliohms .

4.3.4 Perform an insulation resistance test per paragraph 4.3.3, steps 37 through 41.

4.3.5 Attempt to arm the device electrically per paragraph 4.3.3, steps 2 through 9. Record the arm current on the oscilloscope. Be sure to listen for any sound which may be emitted by the device.

4.3.6 Separate the Barrier-Booster from the Arming-Monitor by removing the lockwire and four screws holding the two together.

4.3.7 Measure and record the Barrier-Booster torque in both directions. Attempt measurement with the low scale (0-40 in-oz) torque watch gage, and then with the high scale (0-200 in-oz) torque watch gage if necessary.

4.3.7.1 Place Barrier-Booster & pyrotechnics in a bag. Reset in shipping container.

4.3.8 Perform the electrical function test per STW7-2767, para 4.3.4, steps 1 thru 11. Record arm current on the oscilloscope.

4.3.9 Determine the minimum cycle voltage per paragraph 4.3.3 of STW7-2767, steps 1 through 16.

4.4 Disassembly

4.4.1 Remove the lockwire and four screws holding the NAJOH-12-8P electrical connector to the Arming-Monitor. Carefully remove the connector and inspect for broken or loose solder joints. If a broken or loose solder joint is found, the disassembly procedure may be terminated at this point.

4.4.2 Remove the three screws holding the 1U50625-01 retainer at the bottom of the Arming-Monitor and remove the retainer. Visually inspect the retainer and the exposed 1U50621-01 shaft and o-ring.

4.4.3 Remove the lockwire and four screws holding the 1U50600-01 actuator assembly in place. Rotate the actuator assembly in 1U50609-01 Arming-Monitor housing and remove the 1U50621-01 arming shaft. Rotate the actuator assembly back in place for removal.

4.4.4 Unsolder the wires from the connector removed in step 1.

4.4.5 Remove the 1U50600-01 actuator assembly from the 1U50609-01 Arming-Monitor housing.

4.4.6 Examine the 1U50601-01 & 1U50602-01 switch decks and wiring for any signs of damage or defective connections. If a defective connection is found the disassembly procedure may be terminated at this point.

4.4.7 Remove the three screws holding the 1U50623-01 stop plate. Remove the stop plate, teflon insulators, and switch deck assemblies (including 1U50601-01, 1U50602-01, 1U50620-01, 1U50622-01, & 1U50670-01.) Inspect the switch decks for signs of damage.

4.4.8 Remove the three screws holding the 1U506710-01 gear housing to the 1U50612-01 motor housing. Do not remove the clutch assembly (including 1U50640-01, 1U50661-01, & 1U50677-01). Remove the 1U50610-01 gear housing and the 1U50636-01 brush plate from the 1U50612-01 motor housing.

4.4.9 Inspect the wires which lead into the 1U50632-01 field windings in the 1U50612-01 motor housing for any signs of damage.

4.4.10 Inspect the 1U50608-01 armature assembly for signs of damage.

4.4.11 Inspect the 1U50636-01 brush plate assembly for signs of damage or defective connections.

Photographic records will be taken or any unusual condition which can be recorded in this manner.

5.0 Reports

5.1 Flash Report

A flash report shall be prepared and submitted within 24 hours of the conclusion of the disassembly of the unit.

5.2 Final Report

A complete and final report shall be prepared and submitted within fifteen (15) working days after completion of the investigation.

MORTON THIOKOL INC.
Space Operations

ATTACHMENT A

Continuity & Resistance Check

SAFE Condition:

Safe Motor Coil	J1-C	J1-B	OPEN	OPEN > 2 MEGOHMS
Arm Motor Coil	J1-A	J1-C	15-25OHMS	OPEN > 2 MEGOHMS
Safe Monitor	J1-H	J1-G	.2 OHM MAX	.073 OHMS
Arm Monitor	J1-F	J1-E	OPEN	OPEN > 2 MEGOHMS

FAILURE INVESTIGATION OF S&A DEVICE 016

20 JULY 1989
12:30 P.M. MDT

- RESULTS AT EATON (S&A COMPONENT MANUFACTURER)
  - PIN-TO-PIN CHECKS WITH MULTIMETER
    - ALL RESISTANCE CHECKS WITHIN DESIGN ACCEPTANCE LIMITS
    - ARM COMMAND CIRCUIT RESISTANCE IN PARTICULAR WAS 18.7Ω, WHICH IS NORMAL (15-25Ω REQUIRED)
  - CHECKOUT CONSOLE RESISTANCE CHECKS
    - ALL RESISTANCE CHECKS WITHIN DESIGN ACCEPTANCE LIMITS
    - ARM COMMAND CIRCUIT RESISTANCE IN PARTICULAR WAS 18.6Ω, WHICH IS NORMAL (15-25Ω REQUIRED)
  - CYCLING RESULTS
    - S&A WAS CYCLED AT 24 VDC
    - CYCLE TIMES WERE WITHIN EXPECTED RANGE

      CYCLE TIME TO ARM -- 0.905 SECOND (2.0 SECONDS MAXIMUM ALLOWED)

      CYCLE TIME TO SAFE -- 1.014 SECONDS (2.0 SECONDS MAXIMUM ALLOWED)

FAILURE INVESTIGATION OF S&A DEVICE 016

20 JULY 1989
12:30 P.M. MDT

- LOADED BARRIER-BOOSTER (B-B) ASSEMBLY SEPARATED FROM ARMING-MONITOR (A-M) ASSEMBLY
  - B-B TORQUE READINGS WERE WITHIN EXPECTED RANGE

    TORQUE IN ARM DIRECTION -- 52 IN-OZ (NO REQUIREMENT CURRENTLY)
    TORQUE IN SAFE DIRECTION -- 48 IN-OZ (NO REQUIREMENT CURRENTLY)
- COMPLETE ELECTRICAL CHECKOUT OF A-M ASSEMBLY PER THE ACCEPTANCE TEST PROCEDURE (ATP)
  - CYCLE TIMES NORMAL AS EXPECTED
  - RESISTANCE CHECKS WERE ALL NORMAL
- VIBRATION OF A-M
  - RANDOM VIBRATION AT 3.4 GRMS (TRANSPORTATION VIBRATION LEVELS) PER THE ATP FOR 4 MINUTES PER AXIS, 2 MINUTES IN EACH POSITION.
    - FLOW WENT -- ELEC ARM, VIBRATE X, ELEC SAFE, VIBRATE X, VIBRATE Y, ELEC ARM, VIBRATE Y, VIBRATE Z, TRY TO ELEC SAFE, STOP.
    - SOME VIBRATION TIMES WERE LONGER THAN PLANNED WHEN CONNECTIONS LOOSENED
  - MULTIMETER WAS ATTACHED TO UNIT AND RESISTANCE WAS VISUALLY MONITORED THROUGHOUT THE VIBRATION
  - UNIT WAS NOT CYCLED WITH THE CHECKOUT CONSOLE. CYCLE TIMES WERE NOT MEASURED.
  - VIBRATION RESULTS -- SEE TABLE

FAILURE INVESTIGATION OF S&A DEVICE 016

20 JULY 1989
12:30 P.M. MDT

- VIBRATION OF A-M (CONT)

AXIS		VIBRATION TIME	RESISTANCE BREAK?	CYCLE VOLTAGE
X (VERTICAL)	ARM	2 MINUTES	NO	28 VDC
	SAFE	2 MINUTES	NO	N/A
Y (HORIZONTAL)	SAFE	4 MINUTES	NO	28 VDC
	ARM	2 MINUTES	NO	N/A
Z (HORIZONTAL)	ARM	4 MINUTES	NO	WOULD NOT CYCLE
	SAFE	NONE		

- STATIC ELECTRICAL CONTINUITY CHECKS IN ARM POSITION
  - SAFE MOTOR RESISTANCE -- 19.0Ω (15-25Ω REQUIRED)
  - ALL OTHER RESISTANCE READINGS NORMAL
- ATTEMPT TO ELECTRICALLY SAFE
  - UNIT DID NOT SAFE
  - CIRCUIT PULLED 1.2 AMPS, WHICH IS NORMAL (0.96-1.6 EXPECTED, NO REQUIREMENT)
- MANUAL SAFE -- SUCCESSFUL AT 32 LBS, WHICH IS NORMAL (20-40 LBS REQUIRED)
- STATIC ELECTRICAL CONTINUITY CHECKS IN SAFE POSITION
  - ARM MOTOR RESISTANCE -- 19.7Ω (15-25Ω REQUIRED)
  - ALL OTHER RESISTANCE READINGS NORMAL

FAILURE INVESTIGATION OF S&A DEVICE 016

20 JULY 1989
12:30 P.M. MDT

- RESULTS AT KSC
  - ELECTRICAL CHECKOUT CABLE WAS INVESTIGATED BY THE KSC ELECTRICAL MISHAP LAB
  - BACKGROUND
    - CABLE WAS A REPLACEMENT OBTAINED BY KSC AND NOT CERTIFIED TO THE 8U50539 REQUIREMENTS
    - CABLE HAS BEEN USED FOR SOME TIME
    - KSC HAS SECOND IDENTICAL CABLE
  - CABLE WAS PHOTOGRAPHED. THERE WAS NOTHING VISUALLY ABNORMAL.
  - FOUND INTERMITTENT DISCONTINUITY IN COMMON RETURN OF ACTUATOR CIRCUIT LINE.
  - LOCATED DEFECT TO BE 1-3 INCHES FROM THE S&A CONNECTOR BY FLEXING CABLE
  - DEFECT ALSO FOUND ON RADIOGRAPHS AT SAME LOCATION
  - SET CABLE ASIDE FOR TIME BEING

FAILURE INVESTIGATION OF S&A DEVICE 016

20 JULY 1989
12:30 P.M. MDT

- PLANS FOR NEXT STEPS
  - DISASSEMBLE A-M
    - TEAM HYPOTHESIZES THAT THERE IS MECHANICAL INTERFERENCE ABOVE THE CLUTCH ASSEMBLY IN THE GEAR OR MOTOR REGION
  - PULL THE LIFE HISTORY OF THIS A-M AND THE FLIGHT 5 A-Ms AND COMPARE
  - PULL THE HISTORY ON THE CABLES USED AT KSC
  - PROVIDE KSC WITH PROPERLY PEDIGREED CABLE
- CONCLUSIONS SO FAR
  - THE KSC CHECKOUT CABLE USED TO CHECK THE LATEST GROUP OF S&As IS DEFECTIVE
  - THE KSC CHECKOUT CABLE MAY OR MAY NOT HAVE CAUSED S&A 016 TO FAIL CHECKOUT AT KSC
  - IF THE FLIGHT S&As WERE NOT CAPABLE OF ELECTRICAL SAFING IN THE EVENT OF A LATE ON PAD ABORT (CAUSED BY SSME IGNITION VIBRATION,) THE UNITS COULD BE MANUALLY SAFED

FAILURE ANALYSIS REPORT
(FAR 2125)

7/18/89

ATTACHMENT 3

IV CONCLUSION:

The Arming Monitor (SN 0000042R2) was subjected to the test procedure provided in the updated Thiokol ETP #0518. (Attachment 1 of this FAR). Telephonic reporting to NASA and Thiokol was conducted by NASA/Thiokol Investigative Team Members (ITM's). Eaton Investigative Team members provided technical assistance and conducted required testing per approved test procedures.

The unit passed all aspects of normal acceptance testing. An additional vibration testing was conducted per Attachment 2 instructions. (Motor current drawn during ATP and vibration test plots are shown in Addendum #1 to this attachment)

The unit failed to safe after vibration in the Z axis in the Arm position (Ref Attachment 2).

Careful disassembly of the unit revealed the motor shaft bearing (P/N 1U506640) located at the upper end of the motor (The end opposite the bearing nearest the motor brushes) was very rough and tended to oppose rotation when rotated slowly. The bearing was not frozen however, it did exhibit high friction and a very rough feeling to the touch. This was the only significant anomaly found during the tear down. There is no evidence that the bearing was the cause of the failure noted at Kennedy Space Center (KSC). Review of performance records show the actuation time was higher after the bearing was replaced at the units last full refurbish ment. The actuation time was within ATP requirements. Eaton feels the bearing was finally damaged by the additional vibration imposed during testing during this investigation. The bearing is made of AISI E52100 steel with an ABEC-1 tolerance requirement.

The bearing material is not stainless steel and could be affected by corrosion and brinneling during vibration. The brinneling of this type of steel is well documented especially when used without lubrication. Eaton has replaced this type bearing with stainless steel material bearings for the General Dynamics Advanced Cruise Missile (ACM), the Boeing B1B version of the Air Launched Cruise Missile (ALCM) and in the United Technologies Chemical Division Titan Destruct Device. All other new designs for our product line also uses stainless steel bearings with a better tolerance rating of ABEC-5.

The unit was re-built with a new 1U50664 Bearing and subjected to testing (per addendum 2 to this attachment). The unit operated flawlessly during and after the vibration schedule shown in addendum 2.

Recommendations:

1. The bearing (PN 1U50664) should be changed to a stainless steel material with a better tolerance rating of ABEC-5.

2. The bearing should be lightly lubed with the same oil used for the brush bearing during installation.

3. The 1U50664 bearing should be replaced during the next normally scheduled refurbishment of each unit in the field.

4. The records of all A&M's should be reviewed for analysis of actuation times between the latest refurbishment ATP and the previous ATP. Units with 20 percent or greater increase in actuation time should be retested and evaluated for potential early refurbishment.

RANDOM VIBRATION TEST SETUP

current date : 07/20/89
: 09:16:29
last updated : 05/30/89
: 15:44:19

TEST SETUP ID :....................................>THIOKOL

TEST DESCRIPTION : B&B P/N 1U52293-02. S/N 0000055 R1 AXIS Z STAMP

APPROXIMATE ARMATURE WEIGHT (LB) : ....>45.0
APPROXIMATE LOAD WEIGHT (LB) : ....>10.0

INPUT SENSITIVITY :...............................>2
(1=10mV/g, 2=100mV/g, 3=1000mV/g)

CONTROL CHANNEL INPUT SEQUENCE : ....>1,
(1=CH1, 2=CH2, 3=CH3, 4=CH4, 5=CH5, 6=CH6, 7=CH7, 8=CH8)

MAXIMUM ANALYSIS FREQUENCY : ....>4
(1=250Hz, 2=625Hz, 3=1250Hz, 4=2500Hz)

LINES/FREQUENCY RESOLUTION : ....>3
(1=125/20Hz, 2=250/10Hz, 3=500/5Hz)

DEGREES OF FREEDOM, DOF (25 to 400) : ....>200
+/- 0.7 dB ACCURACY WITH 90% CONFIDENCE
DISCOUNT FACTORS, Ky = Kx = 53

FRAMES/LOOP, L (4 to 52) : ....>26

VARIABLE (V) OR FIXED (F) BANDWIDTH CHECKING : >V
(5-200Hz, 5Hz BW; 200-1000Hz, 10Hz BW; 1000-2500Hz, 25Hz BW)

NUMBER OF LINES TO TRIGGER ALARM : ....>1

NUMBER OF LINES TO TRIGGER ABORT : ....>1

GRMS ABORT LIMIT (+dB) : 0.8 (-dB) : 0.8

N-SIGMA DRIVE LIMITING (N=NONE, 2to4) : ....>3.0

ANALYSIS CHAN SCALING (re CONTROL) (.1 to 1) :. 0.3

AUTO RANGE START LEVEL (-20.0 to -6.0 dB) :....>-10.0

AUTO RAMPING (1=SLOW, 2=MED, 3=FAST) : ....>1

..ULTIPLE LEVEL TEST (Y, N) : ....>N
LEVEL (-dB wrt REF) : 0.0
DURATION : 0 HRS 1 MIN 0 SEC

TEST SETUP ID : THIOKOL

REFERENCE PSD (0 dB)

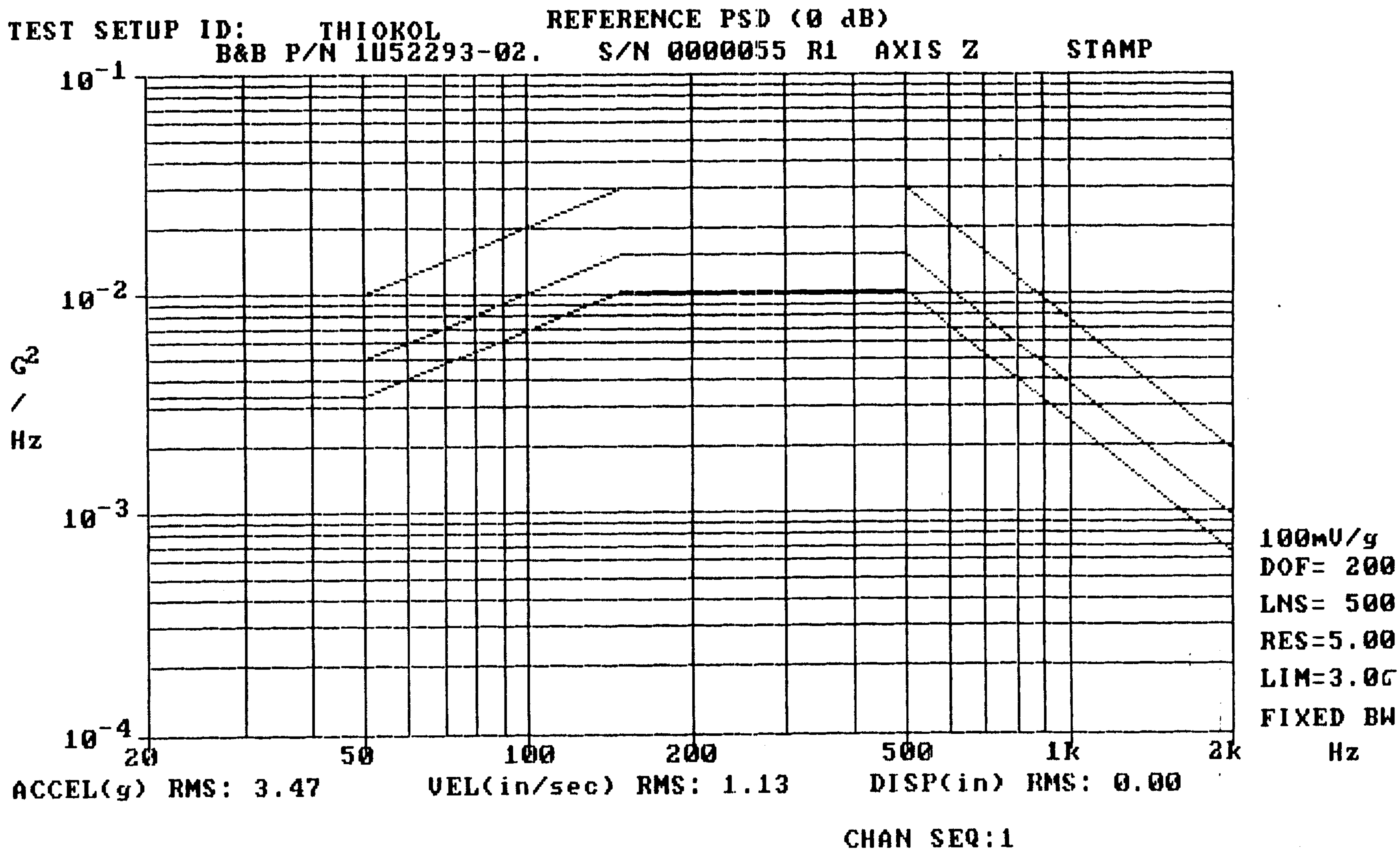
INITIAL SLOPE (dB/OCT) : 0.000000

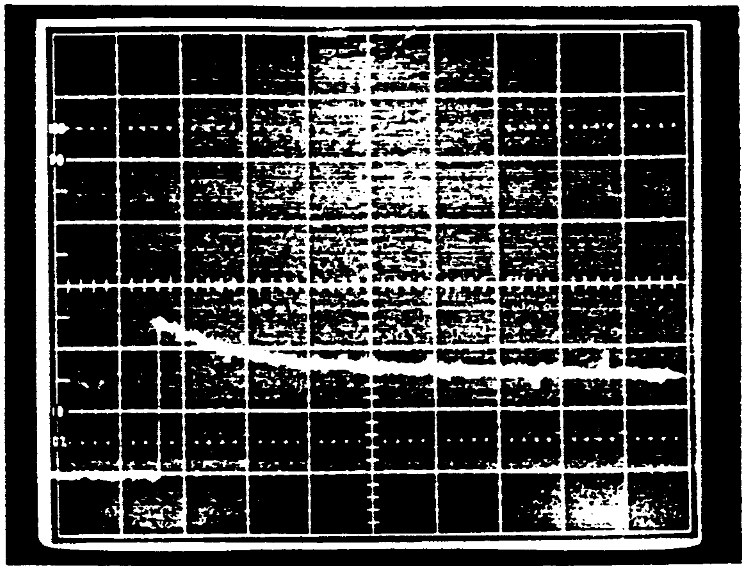
FINAL SLOPE (dB/OCT) : -6.000000

ACCEL(g)Rms=3.47 VEL(in/sec)Rms=1.13 DISP(in)Rms=0.00

BRKPT NO.	FREQ (Hz)	LEVEL (GSQR/Hz)	ALARM (+dB)	ALARM (-dB)	ABORT (+dB)	ABORT (-dB)
1	20.00	0.0050000	3.0	1.7	4.0	2.5
2	50.00	0.0050000	3.0	1.7	4.0	2.5
3	150.00	0.0150000	3.0	1.7	4.0	2.5
4	500.00	0.0150000	3.0	1.7	4.0	2.5
5	2000.00	0.0009375	3.0	1.7	4.0	2.5

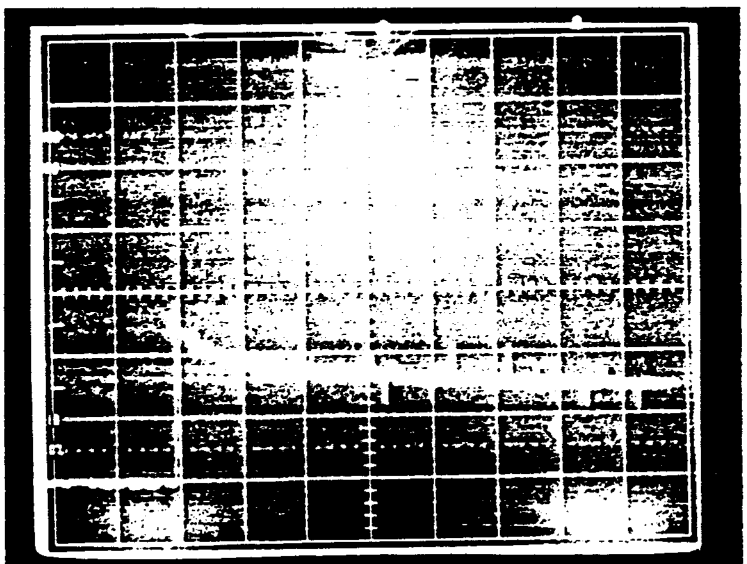
LO FREQ= 20.00Hz | HIGH FREQ=2000.00Hz | FREQ RES= 5.00Hz |EST PP DISP= 0.0 in


TEST SETUP ID: THIOKOL
REFERENCE PSD (0 dB)
B&B P/N 1U52293-02. S/N 0000055 R1 AXIS Z STAMP
10^{-1}
10^{-2}
10^{-3}
10^{-4}
G^2 / Hz
20
50
100
200
500
1k
2k
Hz
100mV/g
DOF= 200
LNS= 500
RES=5.00
LIM=3.0G
FIXED BW
ACCEL(g) RMS: 3.47
VEL(in/sec) RMS: 1.13
DISP(in) RMS: 0.00
CHAN SEQ:1



ARM TO SAFE 7/18/89

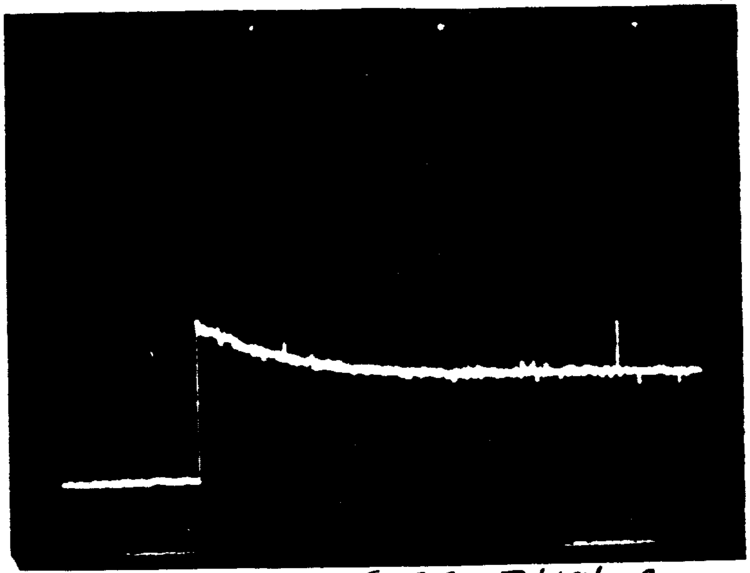
MOTOR CURRENT VS TIME ARM TO SAFE
7/18/89 SETTINGS:
VERTICAL 50 MV/CM HORIZ 100 MILLISECONDS/CM



SAFE TO ARM 7/18/89

MOTOR CURRENT VS TIME SAFE TO ARM
7/18/89 SETTINGS 50 MV/DIV VERT.
100 MILLISECONDS/DIV HORZ

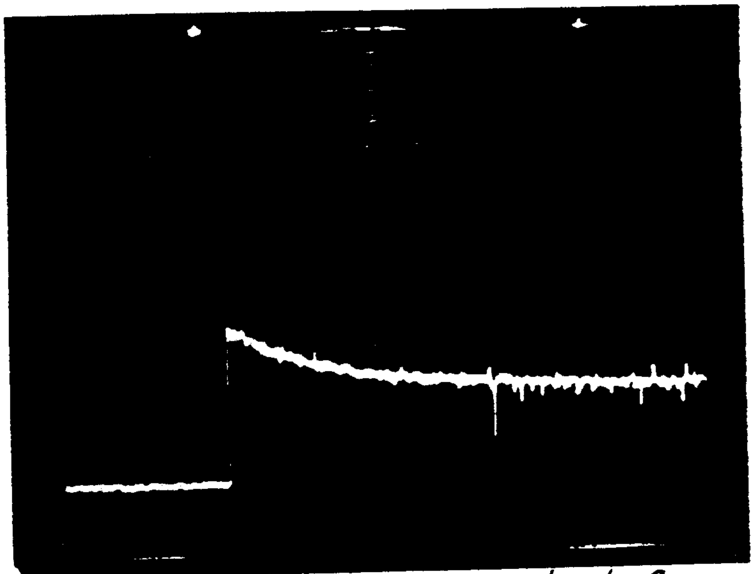
ADDENDUM 1 TO
ATTACHMENT 3



ARM TO SAFE 7/19/89

MOTOR CURRENT VS TIME

ARM TO SAFE 7/19/89
VERT 50 MV/DIV
HORZ 100 Msec/DIV



SAFE TO ARM 7/19/89

MOTOR CURRENT VS TIME
SAFE TO ARM 7/19/89
VERT 50 MV/DIV
HORIZ 100 Msec/DIV

ADDENDUM 1 TO
ATTACHMENT 3

Completed 7/22/89

ARM-MONITOR ASSEMBLY PART NUMBER: 1U50266
S/N 0000042R2

1.0 Cycle unit 69 cycles

1.1 Record Safe & Arming Times.

2.0 Perform Acceptance Test vibration per STW7-2767 Paragraph 4.3.1

3.0 Perform Flight Level Vibration

4.0 Perform minimum cycle voltage per STW7-2767 Paragraph 4.3.3

4.1 Record minimum Arm cycling voltage 9.9 Volts

4.2 Record minimum Safe cycling voltage 9.6 Volts

4.3 Cycle to Arm at 24V - one (1) time Record time .700 Seconds

4.4 Cycle to Safe at 24V - one (1) time Record time .692 Seconds

5.0 Disassemble Arm-monitor assembly - visually inspect all details for obvious damage -

NOTE: Verify condition of 1U50664-03 Bearing. Record condition of details inspected.

6.0 Inspect all detail parts - gear housing thru top bearing in top of motor - record dimensions.

7.0 Reassemble Arm-monitor assembly per approved.

Addendum 2 to
Attachment 3

8.0 Perform assembly test procedure per STW8-2767 Paragraph 4.3.2.2. Record ___________

9.0 Perform Acceptance Test Vibration
NOTE: Duplicate test cycles performed on 7-19-89

10.0 Perform minimum cycle voltage per STW7-2767 paragraph 4.3.3

10.1 Record minimum arm cycling voltage

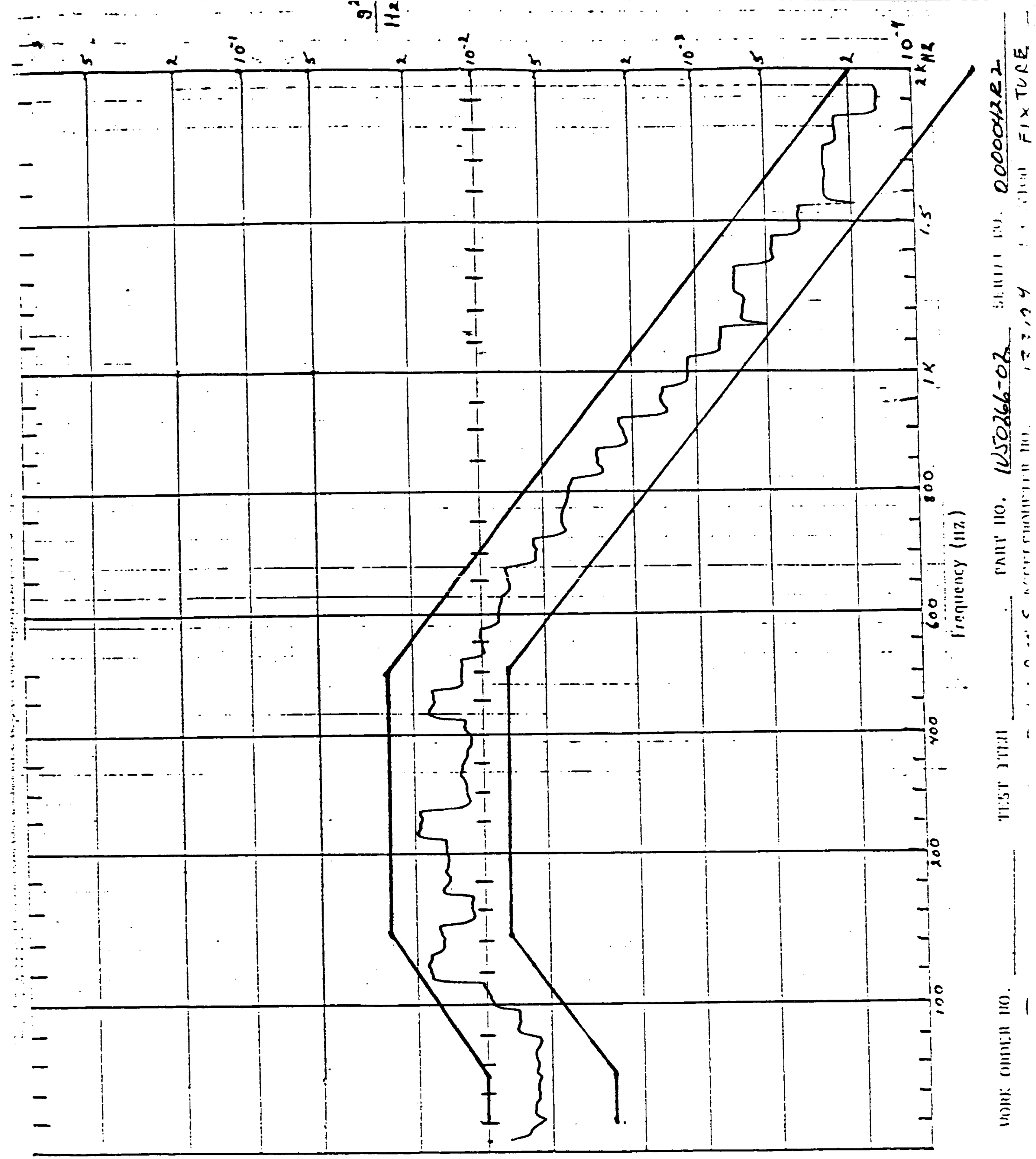
10.2 Record minimum safe cycling voltage

10.3 Cycle to arm at 24V - one (1) time
Record time ____________

11.4 Cycle to Safe at 24V - one (1) time
Record time ____________

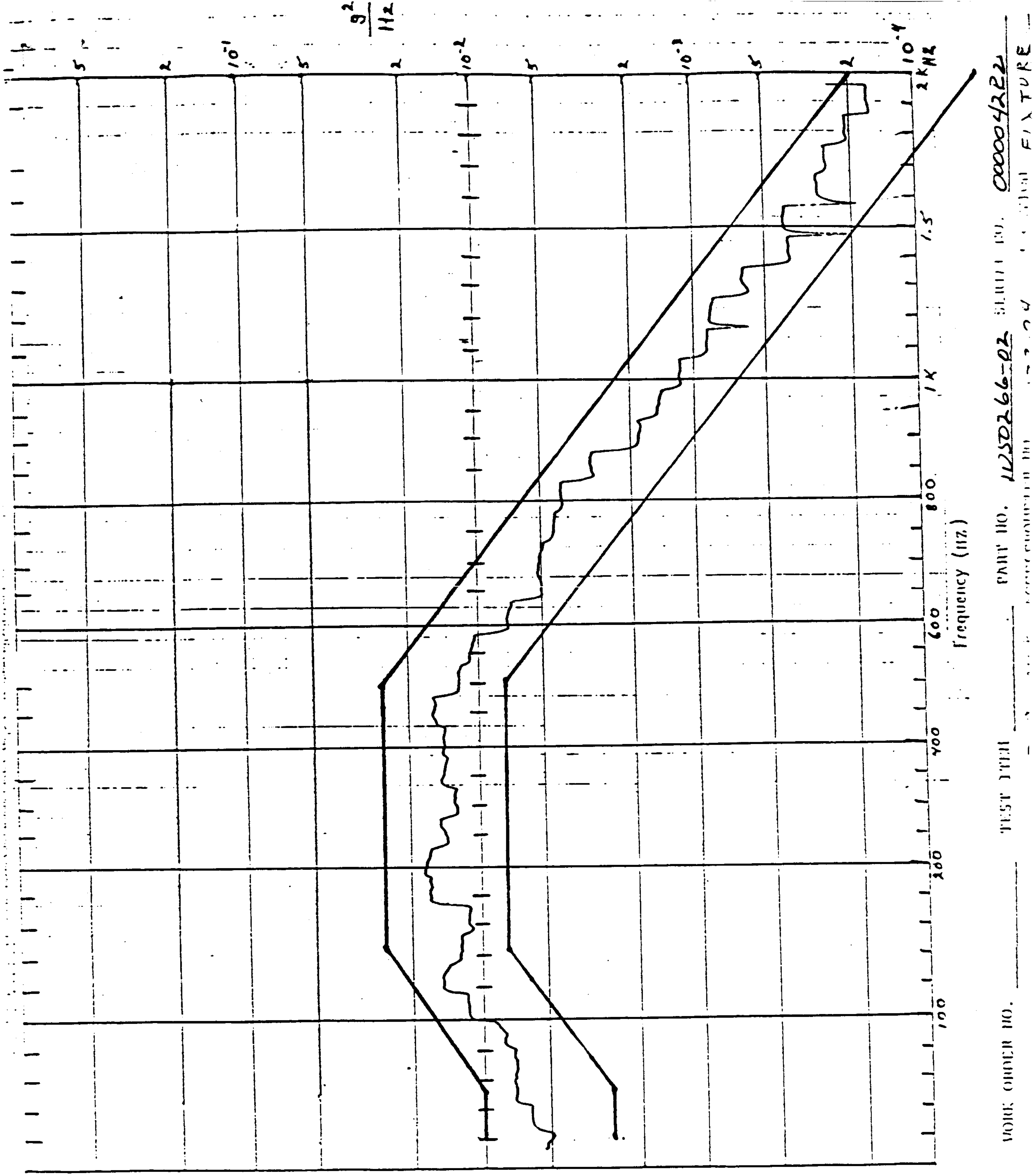
11.0 Perform assembly test procedure per STW7-2767 paragraph 4.3.2.2. Record.

Addendum 2 to
Attachment 3



g²/Hz
Frequency (Hz)
WORK ORDER NO.
TEST ITEM
PART NO. 1U50266-02
SERIAL NO. 0000042R2
FIXTURE

7-22-89



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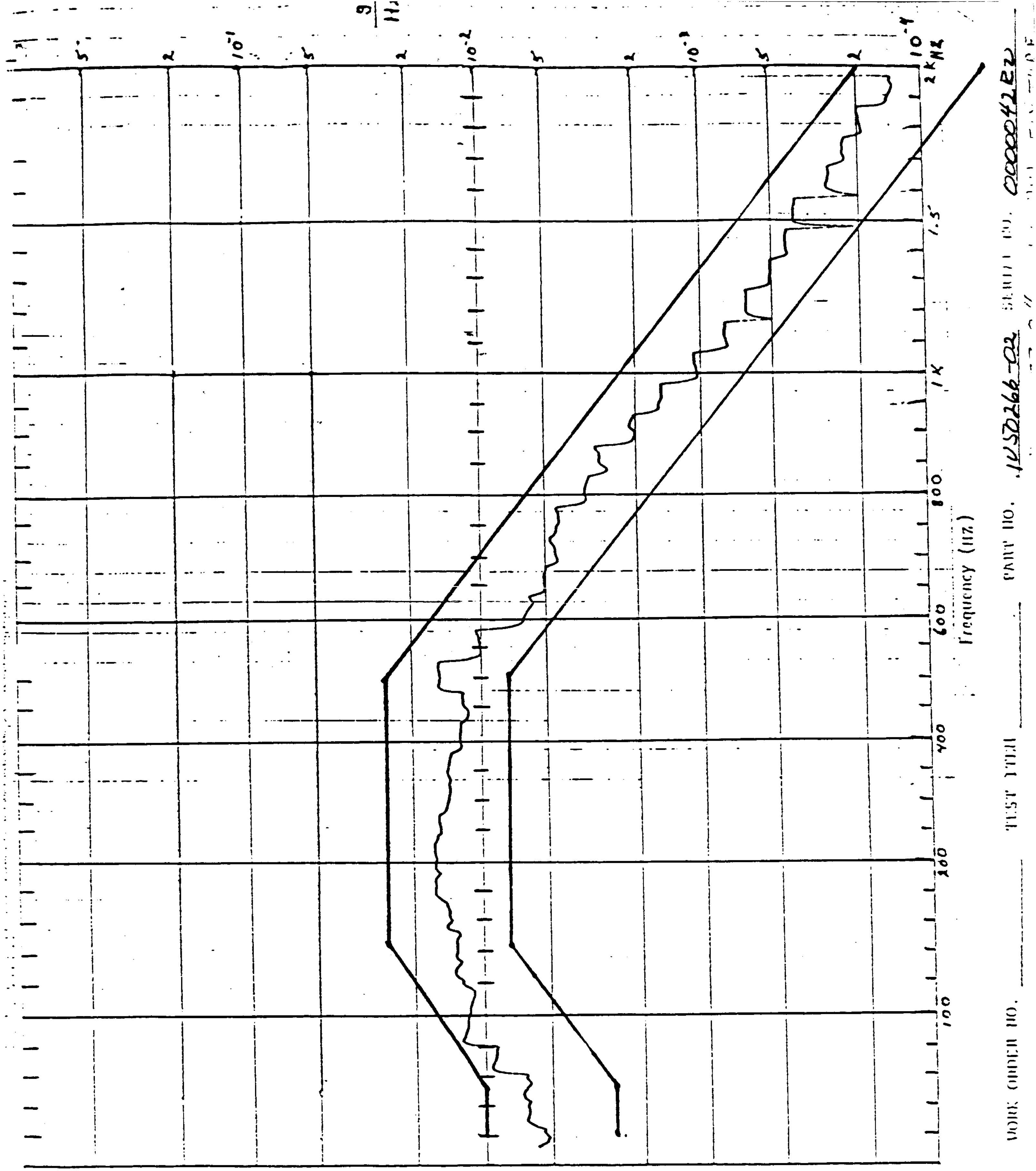
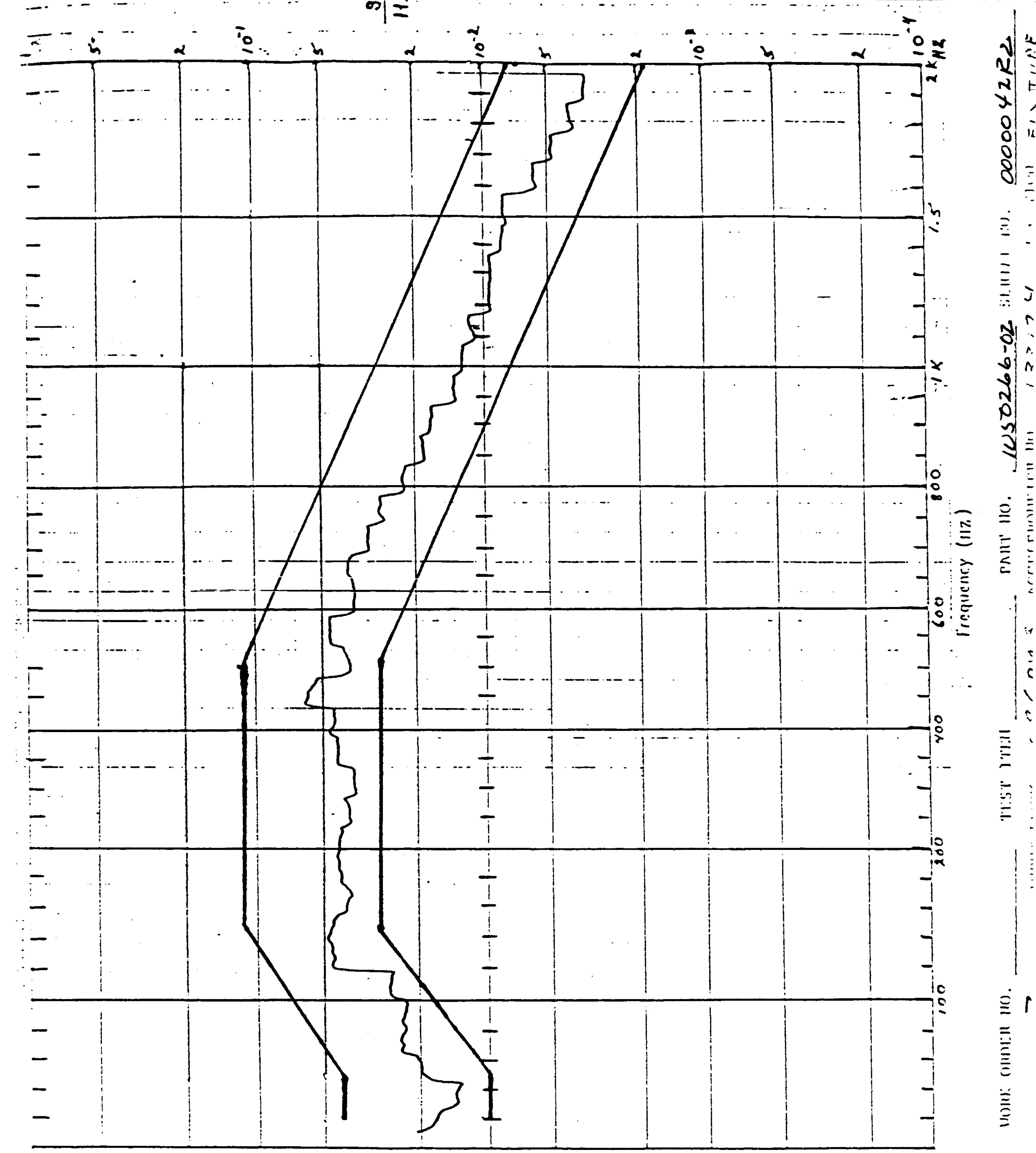
ADDENDUM 2 TO
ATTACHMENT 3

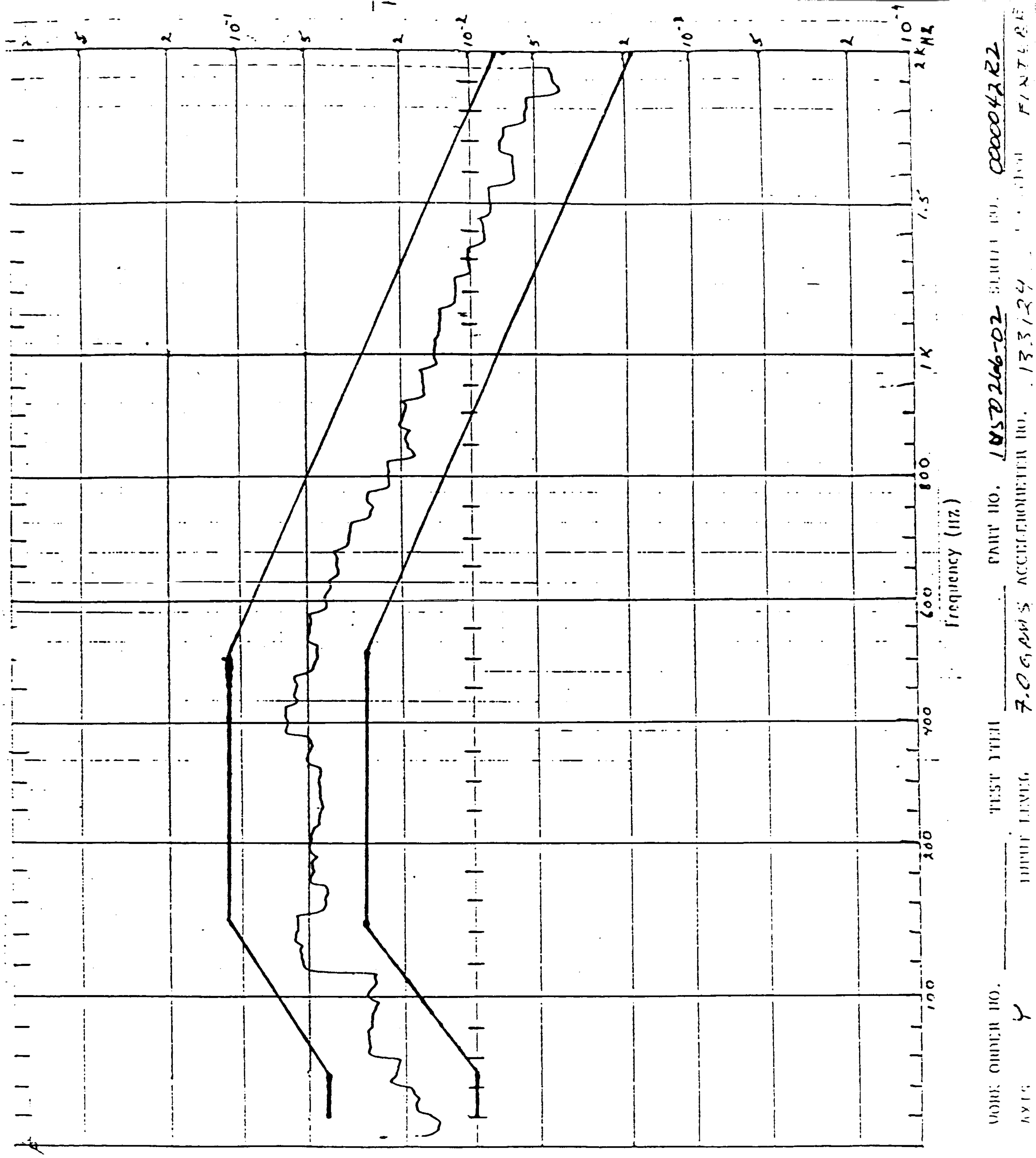

Frequency (Hz)
PART NO. 1U50266-02
SERIAL NO. 0000042E2
TEST TITLE
WORK ORDER NO.

7-22-87

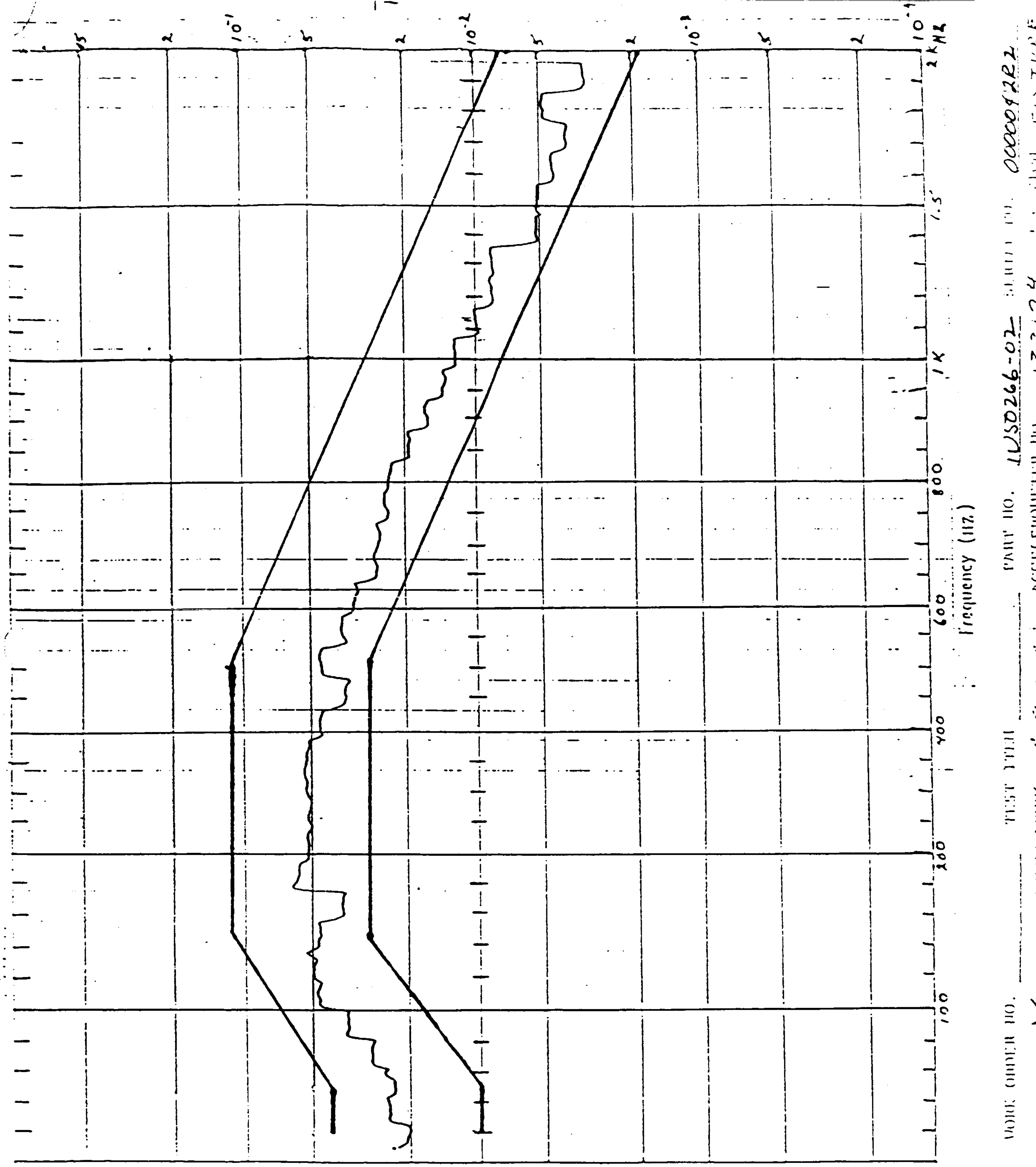


7-22-87

ADDENDUM 2 TO
ATTACHMENT 3



ADDENDUM 2 TO
ATTACHMENT 3



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ADDENDUM 2 TO
ATTACHMENT 3

2-22-87